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EXPERIMENTS TO DETERMINE NEIGHBORHOOD REACTIONS TO LIGHT AIRPLANES WITH AND WITHOUT EXTERNAL NOISE REDUCTION

By Fred S. Elwell

Aeronautical Research Foundation

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SUMMARY

The work reported was part of a program of experimentation with external noise reduction on light airplanes. This particular study was in effect a byproduct survey conceived to utilize already available equipment and personnel to further the findings of the original research and to determine reactions in populated neighborhoods to light aircraft with and without noise-reduction equipment.

Two light airplanes modified by reduction gears, four-bladed propellers, and engine exhaust silencers were flown in comparison with two standard airplanes at a number of sites of the type that might be useful as "close-in" landing strips within the metropolitan area of Boston, Mass.

The objective was to ascertain the neighborhood reactions to the noise of light airplanes flown close to residential properties of varying income levels, population densities, and proximity to trade centers in order to determine whether the degree of noise reduction found to be practicable in the major phases of the research program produced a significant reduction in neighborhood objection to such aircraft operations.

The findings indicate that at the 10 sites within and about metropolitan Boston the degree of noise reduction previously found to be aerodynamically and structurally feasible did eliminate substantially all neighborhood objections to noise per se.

The tests were not extensive enough to determine whether other manifest objections such as fear of low-flying aircraft and possible property devaluation would still have resulted in sustained objections. Neither was it possible to ascertain the importance of the noise nuisance relative to other complaints raised against close-in operation of aircraft. The evidence did clearly suggest that when the noise nuisance is minimized to the extent found feasible, the number and severity of other objections also diminish - evidently because the flight operations are noticed less when heard less.

INTRODUCTION

The experiments reported herewith were conducted during the years 1947-1950 by the Aeronautical Research Foundation under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

The Trustees of the Foundation originally decided to undertake research in the area of external noise reduction because they had concluded that:

> The development of civil aviation, insofar as the utilization of light airplanes is concerned, has been seriously retarded by the unwillingness of communities to permit an adequate number of conveniently located landing areas. This same lack of ground facilities materially affects the safety of the vehicle.

To test the hypothesis that one of the principal objections might be due to airplane noise, the principal research by the Foundation has been on external noise reduction with both tractor- and pusher-type light airplanes. The primary objective of the project was to determine ways and means of reducing external noise without impairing the aerodynamic, structural, or operational effectiveness of light aircraft. Insofar as possible, utilizing equipment and personnel already available, the secondary objective discussed in this report was that of ascertaining the extent of noise-level reduction required to reduce significantly the noise nuisance in nearby neighborhoods.

The Foundation, therefore, tested neighborhood reactions by flying both standard and modified airplanes at locations of the type which have customarily given rise to noise objections.

The project was under the general direction of Dr. Lynn L. Bollinger, Executive Director of the Foundation, and under the technical direction of Professors Leo L. Beranek, Otto C. Koppen, and C. Fayette Taylor of the Massachusetts Institute of Technology, and Mr. Arthur H. Tully, Jr.,[1] Assistant Director of Research of the Harvard Business School.

Mr. Joseph Garside, as Director of Operations for the Foundation, directed the control of airplane safety and maintenance, piloted the aircraft on many occasions, and acted as ground observer at some of the test sites.

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[1]Executive Director of the Foundation as of January 1, 1950.

Mr. William W. Dean, Administrative Assistant of the Foundation, during the summer of 1949, provided assistance in piloting the airplanes and taking sound measurements and acted as ground observer at many of the test sites.

Mr. John P. Roberts, Sound Engineer of the Foundation, assisted in this project by taking sound measurements and acted as ground observer at many of the test sites.

The following organizations and individuals generously contributed equipment and assistance on this project:

Aircooled Motors, Inc., lent the experimental geared engine used in the modified Stinson and also in the modified Goodyear.

Goodyear Aircraft Corp. gave the castering landing gear for the modified Stinson and lent the Goodyear amphibian for experiments.

Lycoming Division, AVCO Mfg. Corp., gave the engine for the experimental Cub airplane.

Maxim Silencer Co. gave the silencers for the modified Stinson.

Sensenich Bros. provided all experimental propellers at cost.

Stinson Aircraft Division, Consolidated Vultee Aircraft Corp., gave the Stinson airplane for experiments.

Mr. Joseph Garside, President of Wiggins Airways, gave use of his company's shops and facilities and contributed flight time to make aerial surveys for possible test sites in the southern sectors of metropolitan Boston.

Mr. Julius Goldman, President of Revere Airways, Inc., contributed flight time to make aerial surveys for possible test sites in the northeastern sector of metropolitan Boston.

Mr. John T. Griffin, President of East Coast Aviation Corp., contributed flight time to make aerial surveys for possible test sites in the northwestern sector of metropolitan Boston and, in addition, provided storage space for the Foundation airplanes, on several occasions, at no cost.

Mr. Crocker Snow, Director of the Massachusetts Aeronautics Commission, contributed time and effort to expedite and sanction this project.

DESCRIPTION OF APPARATUS

The apparatus used in this study can be divided into four categories, as follows: The airplanes used together with their power plants, the propellers, the sound-measuring equipment, and the flight-control equipment.

Airplanes and Their Power Plants

The airplanes used were as follows:

(1) ARF Cub, configuration 1: A modified Cub J-3 airplane, shown in figure 1, essentially the same as a standard 1940 J-3 except for a new and larger vertical tail fin and rudder and a complete new engine mount and cowling, equipped as follows:

Engine: Lycoming four-cylinder, direct-drive, rated at 108 horsepower at a crankshaft speed of 2600 rpm.

Propeller speed reduction: Engine modified with the special vee-belt propeller drive illustrated in figure 2.

As shown in figure 2 the drive included a small pulley mounted on the forward end of the engine crankshaft and a larger pulley mounted on an external stationary shaft fastened to the engine crankcase. The upper pulley turned on two antifriction grease-packed bearings located inside the pulley.

Ten Goodyear rubber vee-belts with steel cable cores were used. These belts were each 42 inches in length and 3/8 inch in width. An eccentric arrangement in each upper shaft bracket provided means for adjusting the belt tension. The nominal speed ratio of this combination was 0.632.

Before using this vee-belt drive in flight, it was necessary to subject it to endurance tests totalling approximately 50 hours on the ground. This experimental equipment had a total of over 170 hours in flight, therefore over 220 service hours on the vee-belt-drive assembly.

Exhaust system: Ejector-type, another special feature of this airplane. It was previously developed by Professor Otto C. Koppen of the Massachusetts Institute of Technology for the dual purpose of silencing the exhaust and insuring proper engine cooling under all normal conditions of operation, including excessive full-throttle operation on the ground.

The exhaust ejector consists of a cylindrical tube open at both ends. The tube is attached to the fuselage with its forward end

communicating with the engine compartment and its rear end open to the atmosphere. The engine exhaust manifolds were so arranged as to discharge into a single nozzle which is so located with respect to the tube as to act as an ejector, drawing air from the engine compartment. This compartment has no other exit, and the engine baffles are so arranged that air entering the cooling-air inlet openings and passing over the engine is finally ejected through the ejector tube.

Silencing of the exhaust is assisted by a perforated metal lining within the ejector tube. Between this lining and the outer shell Johns Manville "Flex Blanket" is inserted, so that the arrangement acts as an effective sound absorber. This arrangement was found to furnish adequate air circulation to keep cylinder temperatures well below specified limits, even for continuous running on the ground during the tests of the vee-belt drive. Back-pressure and weight data are as follows: Back pressure, measured in pipe between engine and nozzle, 10 inches of mercury at 2500 rpm, full throttle; weight, 9 pounds.

(2) CAA Cub, configuration 2M, muffled, and 2U, unmuffled: A modified Cub (J-3 type) airplane, loaned by the Civil Aeronautics Administration, shown in figure 3 (muffled, fig. 3(a), and unmuffled, fig. 3(b)), equipped as follows:

Engine: Continental four-cylinder, direct-drive, rated at 65 horsepower at a crankshaft speed of 2300 rpm.

Propeller speed reduction: None.

Exhaust system: Exhaust modified with a Maxim silencer which could be easily detached so that the airplane could be flown with (fig. 3(a)) or without (fig. 3(b)) muffling. Back-pressure and weight data are as follows: Back pressure, measured in pipe between engine and nozzle, with muffler, 0 to 3/16 inch of mercury at 2050 rpm and, without muffler, 0 to 1/8 inch of mercury at 2050 rpm; weight, 14 pounds.

(3) ARF Stinson, configuration 3: A modified 1946 Stinson Voyager 150, equipped as follows:

Engine: Experimental geared Franklin, rated at 180 horsepower at a crankshaft speed of 3050 rpm. However, only approximately 155 horsepower was used since the special four-bladed propeller was designed for that power.

Propeller speed reduction: A planetary gearbox (part of engine) with ratio 0.632.

Exhaust system: Two Maxim silencers, connected to standard exhaust manifolds. Figure 4 shows, photographically, front and rear views of

their mounting on the airplane. Other data concerning these silencers are as follows: Weight, each 12 pounds; supporting brackets, 2.5 pounds; back pressure, measured in pipe between engine and muffler, 4 inches of mercury at 2900 rpm, full throttle.

This airplane was tested in previous noise-reduction research (reference 1) using many different propeller combinations; figure 5 is a photograph of this airplane with the propeller which was used in neighborhood tests. This airplane was not used on many of the test sites because the existing areas, without extensive improvements in many cases, were not large enough for safe operations.

(4) Standard Cub, configuration 4: A production model Cub, used without any modifications, equipped as follows:

Engine: Factory-installed Continental, which delivered 65 horsepower at a crankshaft speed of 2300 rpm.

Propeller speed reduction: None.

Exhaust system: Standard factory installation.

This airplane is shown in figure 6.

In addition, both ARF airplanes and the CAA Cub were equipped with Goodyear castering landing gear.

Propellers

The propellers used were as follows:

(1) A four-bladed, two-piece, wooden-type propeller was used on the ARF Cub. The blade-form curves for this propeller are shown in figure 7. This propeller had a diameter of 80 inches with a nominal pitch of 15°. The modified Cub J-3 with this propeller will be called the ARF Cub, configuration 1.

(2) Two propellers were available for the CAA Cub. The first was a standard two-bladed, fixed-pitch, wooden propeller which had a diameter of 72 inches and a nominal pitch of 14°. Its blade-form curves are illustrated in figure 8. The second propeller was a special four-bladed, one-piece, wooden propeller, having a diameter of 60 inches and a nominal pitch of $16\frac{1}{4}^{\circ}$, made for tests with this airplane but not used, however, since its noise level was higher and its performance poorer than that of the two-bladed propeller. The maximum speed attained by this propeller

was higher by approximately 100 revolutions than that of the two-bladed propeller, but because of the smaller diameter the tip speed was lower. This fact is mentioned here because it is in contrast with the conclusions drawn in reference 1, that is, that increasing the number of blades decreases the noise generation at the same tip speed. The blade-form curves for this unused propeller are shown in figure 9. The CAA Cub with the two-bladed propeller will be called, with the muffler, CAA Cub, configuration 2M, and, without the muffler, CAA Cub, configuration 2U.

(3) The ARF Stinson propeller was a four-bladed, one-piece, wooden type and its blade-form curves are shown in figure 10. It had a diameter of 76 inches with a nominal pitch of 25°. This airplane-propeller combination will be referred to as the ARF Stinson, configuration 3.

(4) The standard Cub, configuration 4, had a propeller which was of the same two-bladed, one-piece type as that used on the CAA Cub. Its blade-form curves are similar to those in figure 8.

Table I gives further information concerning the above propellers and engines and their noise generation.

Sound-Measuring Equipment

The only instrument used in this work was a sound-level meter, General Radio Co., equipped with a microphone supplied by the General Radio Co. and manufactured by Shure Bros.

The noise characteristics of configurations 1, 3, and 4 are reported in detail in reference 1. The sound readings given in table I for those airplanes were taken from that reference and are peak readings at the overhead position only. In addition, new peak levels are reported for the muffled and unmuffled versions of configuration 2 (2M and 2U). Naturally, in all cases, the approaching and departing sound levels are of a lower order and the quieted noise of the airplane close by can be best described as similar to the "whish" of an electric fan.

Flight-Control Equipment

At those sites where the airplane was landed, field markers to outline the landing area and a portable wind sock were used. Since most of the sites were in heavily populated areas, each landing and take-off (in most cases these landings were simulated by low approaches and "dragging" the area) was controlled by a flight supervisor on the ground using colored flags for communication purposes.

NEIGHBORHOOD-REACTION TEST SITES

The sites chosen for testing of noise reactions were picked to represent a cross section of characteristic metropolitan and suburban neighborhoods with varying densities of population, income levels, and property values. Some of the sites had historical evidence of previous objections by local residents to aircraft or to attempts to establish an airport nearby.

A photograph of each site is shown with arrows superimposed vertically to indicate the altitude of the traffic pattern and horizontally to indicate the direction of the circuit. A topographical map of each site shows the traffic-pattern circuit and the ambient sound levels at important points relative to each test airstrip. Table I gives all pertinent statistics of the aircraft used including the peak sound levels of the various aircraft at 500-foot altitude at cruising speed. The maximum flight altitude at the test sites varied from 300 to 500 feet; therefore, the peak levels at the lower altitudes were slightly higher.

The data given in tables II to XI are most significant if the time of day and the day of the week are noted. Generally the hours of the day were picked so that the airplane would be operating part of the time when the male member of the family might be at home or sleeping. This practice was followed because previous evidence (obtained from the Massachusetts Aeronautics Commission; the flight complaint section of CAA Air Carrier at East Boston; the CAA Aviation Safety Branch Office at Norwood Memorial Airport, Norwood, Mass.; and the local airport operators) showed that although the majority of calls are from women (estimated two-thirds to three-fourths) the more serious complainants are men.

A few complaints about the research activity were made in person, but the majority were made by telephone to the local police near each site. All complainants were interviewed and, in addition, occasional spot checks were made to gather sample opinions. Detailed analyses of these complaints are tabulated for each test site surveyed (tables II to XI) and a composite table is shown for comparison and compilation of the totals (table XII).

The modified Stinson was flown at only two neighborhood sites since it was deemed marginal for safe operations at the smaller airstrips, consequently risking the safety of the pilot and equipment. The modified Cub was, therefore, the principal airplane flown in comparison with a special modified CAA Cub and a standard Cub.

Arlington - Spy Pond (Figs. 11(a) and 11(b))

Description of location.- In all areas close to Spy Pond and near the peninsula on its southern edge that was used as an airstrip for simulated landings were middle-income and upper-middle-income homes. The homes nearest the take-off were 20 yards southeast of the flight strip and were part of the incorporated community called Kelwyn Manor. The nearest homes to the west were approximately 250 yards and on the far side of the Concord Turnpike which is a principal highway. The nearest shopping center is East Arlington, which is 1200 yards east of the airstrip. Figure 11(a) is a photograph of the site with the air traffic pattern superimposed and figure 11(b) is a topographical map of the surrounding area with the air traffic pattern and ambient levels indicated.

Flight operation.- The first community-reaction tests were begun at 7 a. m. on Sunday, June 19, 1949. The next tests were made during a supper hour, but reactions to the presence of the airplane for reasons other than noise required a change in operations in the interests of public safety. Since it was rather startling to the average automobile driver to see an airplane come flying at a low altitude over a six-lane highway, as though it were crash-landing into Spy Pond, the risk of multicar accidents occurred when drivers stopped suddenly "to watch the crash." It was, therefore, decided to make all future flights at this site in the early morning.

No other unusual circumstances occurred during the tests which are listed in table II with the complaints received.

Results.- No noise complaints were made concerning the ARF Cub; however, a few complaints were made by conscientious people (four) who thought the airplane was being flown by some "green pilot showing off" and violating regulations. One woman was fearful of her children's safety "in case anything went wrong."

True noise complaints (16) were filed against the standard Cub since it had awakened these people from their sleep by its noise. In addition, three other complaints were filed; two, that the airplane was flying too low against regulations and one, that the airplane was flying "dangerously close" to a home (actual distance, 70 yd - not one of the houses nearest the test strip).

This site had been previously petitioned for use as a seaplane landing base (petition not granted because of noise nuisance caused by the airplane involved which was a light airplane on floats). No one, during these tests, expressed opposition to the possible establishment of a commercial operation in that area. The lack of such a reaction is

unusual. At some of the other sites many people went on record as earnestly opposing the opening of what they presumed was being planned as an airport near their property.

Staff evaluation.- The complaints against the standard airplane seem to confirm the significance of the noise reduction on the modified light airplane. A number of home owners and observers in the locality complimented personnel of the Foundation for having quieted the airplane to such an extent.

Brighton - Metropolitan District Commission Park

(Figs. 12(a) and 12(b))

Description of location.- The airstrip (50 by 400 ft) was an open field, between Soldiers Field Road and the Charles River, which is part of a seldom used Metropolitan District park area. It is bounded on the west and north by the river. Across the river are located, in order according to distance and starting from west to east: A small bathing beach; two private schools, a home for the aged, a large city hospital, and the Harvard infirmary about 400 yards from the airstrip; a heavily populated area of housing, including middle- and low-income groups, starting about 400 yards away; large high-income homes within and continuing beyond 700 yards; and, in the last sector, which starts 600 yards northeast of the airstrip, many high-rental apartment buildings and Harvard Square, a principal shopping center.

To the east, south, and southwest of the airstrip are the Harvard Stadium and athletic buildings and, beyond them, the Harvard Business School, a playground area, a radio and television station and tower (680 ft), an industrial area, low-income houses, and a harness-horse-racing track.

Soldiers Field Road which parallels the site on the east side and Memorial Drive on the opposite side of the river are used by pleasure vehicles only; therefore, the general area is quieter than it would be if these highways were also used by commercial vehicles.

The nearest shopping center is Harvard Square, which is approximately 1100 yards to the northeast of the airstrip. It is also an active focal point for local transportation, being a subway, bus, and trolley terminus.

Flight operation.- The take-off was north toward the hospital followed by a right turn down the river, approximately 200 feet in front of and approximately level with the roof line of the apartment buildings. These buildings and the hospital were subjected to the maximum noise

emission from the airplanes during each circuit of the air traffic pattern. Figures 12(a) and 12(b) show this site and its surrounding area.

The test flying was started at this site on Sunday, December 19, 1948. These initial flights were sporadic at first because of inclement weather. However, a more intensive activity of four successive days late in January 1949 gave additional evidence as to the acceptability of the "quiet" airplane (ARF Cub) within this neighborhood. The flights are tabulated in table III.

There had been some activity at this site, previous to the reaction tests, in the form of demonstrations of the quieted aircraft to public officials. These will be covered under a separate section of this report (see section "Demonstration Sites").

Results.- During the total period of intermittent operations (Oct. 7, 1948, to Jan. 23, 1949), no complaints were received by the surrounding police stations, the Massachusetts Aeronautics Commission, the local CAA, or the Harvard Business School concerning the activity.

Staff evaluation.- It is believed that enough flights were made to provide reasonable indication that the noise emission of the aircraft involved was below that which could be termed a "nuisance level" at this site.

Brockton - Fairgrounds (Figs. 13(a) and 13(b))

Description of location.- The airstrip area (100 by 500 ft) was within the inner oval of the fairgrounds race track. It is located 200 yards east of West Street, 200 yards south of Belmont Street (Rte. 123), 500 yards west of Thurber Avenue, Fairside Road, and Othello Street (connective), and 150 yards north of Forest Avenue. The homes nearest the take-off were those on the far side of Belmont Street. The nearest shopping center is Brockton, 2500 yards northeast of the airstrip. Figure 13(a) is a photograph of the site and figure 13(b) is a map of the surrounding area.

Flight operation.- The tests were begun on Wednesday, February 16, 1949. Two operations totalling 1 hour and 30 minutes with 35 landings were made that day and a third operation lasting 1 hour with 20 landings was made 2 days later.

Results.- The Brockton Police Department was deluged with telephone calls concerning the activity. The Massachusetts Aeronautics Commission made an investigation and exhibit 1 is the result of their findings.

Further testing at this site was not conducted. Nevertheless, the nature of the complaints received did indicate that noise from the modified Cub, configuration 1, had itself created no objections. Ninety-one telephone calls were made concerning the airplane but most of the callers were concerned about the low flying. Some people called to report that the airplane was "in violation" of CAA regulations but approximately 35 to 40 percent of the "complaints" under "Low flying" in table IV were made by solicitous people who called to report that the airplane was "crashing," that it was "in distress," that "its engine quit," and so forth. Investigation revealed that the low noise level of the quieted airplane caused many to think that the engine was "dead." This information recorded by the Foundation is further confirmed in exhibit 1.

Staff evaluation.- The most striking evidence from this site was that there were no complaints against noise per se. It is believed that the fact that the people thought there was something "wrong" with the airplane, that is, that the engine must be dead because it was quiet, is reasonable evidence that the noise level of that airplane was low enough to be "acceptable" in that neighborhood and that the airplane could be operated at that site without further noise reduction.

Canton - Prowse Estate (Figs. 14(a) and 14(b))

Description of location.- The airstrip areas (airstrips 1 and 2 both 100 by 500 ft) were part of the area within a horse-racing oval on a large private estate. It is located east of Washington Street (Rte. 138) and south of the Circumferential Highway (Rte. 128) and is bounded on the south and east by other estates.

To the north is an unpopulated State reservation area. To the west of Washington Street are about 25 homes varying from lower- to upper-middle-income classification and a few large high-income estates. South and east are upper-middle- and high-income estates.

The take-off path was directly west over the most heavily populated area contingent to the site. The landing path was beside the barns and stables of the estate approximately 20 to 30 feet over grazing livestock (airstrip 1).

The nearest large shopping center is Hyde Park, Boston, which is approximately 5000 yards to the northwest of the airstrip. Figure 14(a) is a photograph of the site and figure 14(b) is a map of the surrounding area.

Flight operation.- The first flight at this site was on October 28, 1948, and was a short demonstration using the ARF Cub, with the purpose

of obtaining the owner's approval of using the estate as a test site. The flights were 20 to 30 feet over the heads of cows and thoroughbred horses which continued to graze undisturbed. The estate owner was impressed with the absence of noise nuisance and gave immediate approval to use the area as a test site.

Results.- The six subsequent operations, using various airplanes, evoked complaints only when the standard Cub, configuration 4, was flown. Six noise complaints were filed and one complaint was filed against low flying, as noted in table V.

There were no complaints about the quieted airplanes. However, during the first hour the standard Cub was used three complaints were received by telephone that the airplane had waked the complainants. The other noise complaint was by a property owner who came out at 7:20 a. m. saying the noise had awakened him and that, in addition, it seemed to be bothering the horses. To test this second point the flight path was moved to a new position (airstrip 2) for the next 40 minutes, but the horses still were startled when the airplane was close by. The next flight with the standard Cub was also at the second flight strip. Again the property owner came out and this time (at 7:15 a. m.) insisted that the tests be stopped, saying he did not mind being awakened but that some of the horses were kicking violently in their stalls. During this 15-minute period another objection to the noise was telephoned in.

Staff evaluation.- The reaction at this site, even though the tests had to be curtailed, showed acceptability of the quieted airplanes and disapproval of the standard model. The quieted airplanes had flown there for 8 hours and 10 minutes and had made 110 landings and take-offs without any objection.

The noisy airplane had evoked seven complaints, six of which were definite noise complaints, in less than 1 hour and 15 minutes with only 37 landings. This is in marked contrast with the absence of objections to the modified airplanes and seems to confirm their acceptability at this site.

Medford - Metropolitan District Commission Park

(Figs. 15(a) and 15(b))

Description of location.- The airstrip area (50 by 400 ft) was part of a Metropolitan District park area. It is located south of the Mystic Valley Parkway and west of Winthrop Street and is bounded on the south and west by the Mystic River.

On the north side of the Parkway, the nearest houses within 30 yards are many upper-middle-income homes and east of Winthrop Street are a group of high-rental apartment houses. On the south side of the river, the closest 150 yards from the airstrip, are many hundreds of lower-middle-income houses.

The homes nearest the take-off were those directly north and northwest along the Parkway. The air-traffic-pattern circuit was flown alternately left and right subjecting the public on both sides of the site to the noise-tolerance survey. The nearest shopping center is Medford Square, approximately 900 yards east of the site. Figure 15(a) is a photograph of the site and figure 15(b) is a map of the surrounding area.

Flight operation.- The tests began August 24, 1949, and continued through September 3, and the results are shown in table VI.

Results.- As noted in table VI, no noise complaints were received until the unmuffled version of the CAA Cub was flown. Other complaints were filed concerning low flying (four), fear (one), and objections to the use of that area as an airport (two).

Staff evaluation.- The Foundation expected a deluge of complaints of all types from this heavily populated area but, as will be noted from table VI, relatively few were received. The majority of complaints came from the southern side which, as compared with the northern side, is farther from the site, is a lower-income area, and has an active main-line railroad in its background.

Milton - Cote Estate (Figs. 16(a) and 16(b))

Description of location.- The airstrip area (100 by 500 ft) was a small part of a large (400 by 3200 ft) open field, which ran northwest-southeast on a private estate located southeast of Canton Avenue and southwest of Holmes Lane. Bordering on the southwest and southeast are thickly wooded areas. To the northeast on Holmes Lane are three large high-income estates. Northeast across Canton Avenue are many large estates and a large group of middle-income and upper-middle-income homes approximately 500 yards from the flight strip.

The homes nearest the take-off were those on either side of Canton Avenue closest to the airstrip.

The nearest shopping center is Milton Center, 1400 yards northeast of the airstrip. Figure 16(a) is a photograph of the site; figure 16(b) is a map of the surrounding area.

Flight operation.- Since the area immediately contingent to the site was sparsely inhabited, the two large groups of homes 500 yards north and northeast of Canton Avenue (as shown in the photograph of the site) were also subjected to almost the same intensity of noise as those closest to the airstrip because the airplane was purposely flown close beside the first group and directly over the second densely populated area at a low (300-ft) altitude, on the crosswind and downwind legs.

Results.- The six flight operations and the complaints received (three) are listed in table VII. No complaints were made as a result of flights with the ARF Cub.

Staff evaluation.- The most unusual point concerning results at this site is the fact that neither airplane was reported to be in violation of flight safety because of low flying. A possible explanation might be the fact that this airstrip had been used by the U. S. Navy during World War II as an auxiliary landing field.

Needham - Babson Park (Figs. 17(a) and 17(b))

Description of location.- The airstrip area (100 by 500 ft) was part of an open fallow field within the grounds of Babson Institute. It is located 400 yards north of Great Plain Avenue, 950 yards west of Central Avenue, and 450 yards south of Forest Street. To the west are other fields, wooded areas, and the Institute. The homes nearest the take-off were those on both sides of Great Plain Avenue in line with the take-off path. The site is approximately 2500 yards equidistant from three large shopping centers, Wellesley Hills, Wellesley, and Needham, to the northwest, west, and southeast of the airstrip, respectively. Figure 17(a) is a photograph of the site and figure 17(b) is a map of the surrounding area.

Flight operation.- In order to subject more homes to the tests the airplanes were flown alternately left and right when passing over Great Plain Avenue. This procedure caused the right-turn pattern to pass over a large cluster of middle-income homes on the south side of Great Plain Avenue, over Babson Institute, and close to a children's hospital on the approach to the airstrip. On the left turn the airplane passed close to a group of upper-middle-income homes on the north side of Great Plain Avenue and over a group of high-income homes and estates, locally referred to as the "Gold Coast" of Needham, on the downwind, base, and approach legs, and again passed close to the children's hospital on this approach.

A preliminary demonstration of the ARF Stinson to the selectmen of Needham was made on August 9, 1948, and it was deemed acceptable. On June 10, 1949, the ARF Cub was flown for 30 minutes to determine the best

traffic pattern. Intensive community-reaction tests were begun on July 27 and continued through August 9, 1949. The tests are recorded in table VIII.

The altitude of the flights on the first day of testing (July 27) was too high (600 ft) and also the flights were not directly over but skirted the housing areas and, therefore, did not cause concern or complaints. On the second day (July 29) the flights were at a lower altitude (300 ft) and directly over the homes.

Results.- Evaluating the complaints of the second day brought out an important fact which had a continued bearing on the activity at this site. Quite pointedly the residents feared the establishment of an airport because a newspaper article relative to the first flight stated that Wellesley (land actually in Needham) was to have the first airport using quieted airplanes, at the area. When the flights were apparently going to continue, the residents reacted suddenly and emphatically to forestall the presumed airport construction. (Two flights on July 29; eight complaints.)

Thereafter the complaints began to fall off even to the point of quasi acceptance of the slightly noisier muffled CAA Cub since, by word of mouth within the community, it was now known that the flights were "some sort of research." This information was gathered by a random survey at a few houses each on several different streets in the area between August 1 and the morning of August 8.

A secondary and more violent reaction was evidenced by six legitimate noise complaints against the two flights (Aug. 8 and 9) of the unmuffled CAA Cub. These reactions came from people who had not been bothered by the previous flights made by the other airplanes but quite definitely had been disturbed by the noisier airplane.

Staff evaluation.- In the background of the reactions at this site was a semipolitical situation that may have affected the results.

The collective, though erroneous, assumption was that an owner of an adjacent area was intending to establish an airport. Their assumption was that he was fostering an airport there whether they approved it or not.

Information supporting the above opinion came from seven complainants that are listed as objectors to the establishment of an airport in table VIII. They said that they approved of the airplane and considered it extremely quiet, but they would fight to protect the value of their properties and therefore would not allow an airport in their midst.

The only significant noise complaints were against the unmuffled CAA Cub, configuration 2U. The three prior complaints against the ARF Cub on July 29 and August 1 were all made consecutively by the same person whom the local police characterized as a "chronic" complainant.

Newton - Hurley Pasture (Figs. 18(a) and 18(b))

Description of location.- The airstrip area (50 by 400 ft) was a small part of an open field which is located approximately 450 yards south of the Boston-Worcester Turnpike (Rte. 9) and 350 yards east of Parker Street and is bordered on the east and south by a wooded area, approximately 200 yards in depth between the site and populated areas.

To the east and south beyond the woods are high-income estates and upper-middle-class homes. To the north and west, approximately 150 yards, are upper-middle-class dwellings. The homes nearest the noisiest part of the flight path, the take-off, were in the northwest and west. The take-off was between two groups of houses and nearest the larger group (shown on the right in photograph, fig. 18(a)). The altitude when the airplane first passed by these homes ranged from roof-top level to approximately 150 feet.

The nearest large shopping center is Newton Center, which is approximately 1900 yards to the north of the airstrip. Figure 18(a) is a photograph of the site and figure 18(b) shows the surrounding area topographically.

Flight operation.- Tests were begun at this site on Wednesday, October 27, 1948. The procedure used at this site was to take off west, fly a left-hand circuit of the area twice, and land at the end of the second circuit. The ARF Cub was flown for 1 hour, making 16 landings between 1 and 2 o'clock in the afternoon.

The next operation was on Sunday, October 31, 1948, between the hours of 7:45 a. m. and 12:15 p. m. and later from 2:00 p. m. to 4:30 p. m., totalling 87 landings during those 7 hours of operation.

Results.- On the first day many preschool- and school-age children gathered at the site after the second landing. After the fifth landing a few mothers came out inquiring as to what was going on, showing considerable concern for their youngsters. No other reaction as to the undesirability of the operation was evidenced during this hour.

On the second day many children were again present throughout the tests. Also in attendance were many men and women who expressed varying opinions, which are tabulated in table IX.

One of the men who evidenced fear and also objection to the establishment of an airport showed keen determination to forestall any such activity by stating to a member of the Foundation staff that he would, if necessary, stop the testing survey by a petition to ARF stating that they (the cosigning neighbors) had absolutely no objection to the noise of the airplane but that they did not want the airplane flying near their homes endangering children and/or property.

Nine other (adult male) residents of the immediate area voiced complete approval of the activity, having no objections whatsoever even to the establishment of an airport there if quiet airplanes were to be used exclusively.

Staff evaluation.- Although flights at this site were not conducted over a sufficiently prolonged period to provide conclusive evidence, the nature of reactions suggests that continuing use of this site by aircraft quieted to the degree demonstrated would have evoked few complaints due to noise. Fear of low-flying aircraft was more in evidence and apparently would be an impediment at this site regardless of noise suppression.

Newton-Brighton - Metropolitan District Commission Park

(Figs. 19(a) and 19(b))

Description of location.- The airstrip area (100 by 500 ft) was part of an open field, between Nonantum Road and the Charles River, which is part of a rarely used Metropolitan District park area. It is located north of Nonantum Road (Charles River Basin Parkway) and is bounded on the west, north, and east by the Charles River. On the north side of the river approximately 300 yards from the airstrip are lower-middle-income houses, industrial plants, the Perkins Institute for the Blind, and a United States arsenal. On the river (except in winter when the photograph was taken) were many power and sail boats. To the south were many middle-income and lower-middle-income houses.

The homes nearest the airstrip were those on a hill (elevation, 50 to 150 ft) approximately 200 yards to the south beyond the highway and adjacent railroad tracks. The homes nearest the take-off were those directly west and southwest of the airstrip. The nearest shopping center is Nonantum Square, Newton, which is 1400 yards southwest of the site. Figure 19(a) is a photograph of the site and figure 19(b) is a map of the surrounding area.

Flight operation.- The tests were begun August 15 and were as listed in table X. No complaints were made concerning the airplane throughout the tests.

Results.- Only one inquiry was made from the surrounding area and that did not concern noise. The query was made by the director of the United States arsenal wanting to know if photographs were being taken of the restricted arsenal area.

Staff evaluation.- This site, it may be concluded, is within an area that is conditioned to a high noise level caused principally by an active main-line railroad.

Winchester - Country Club (Figs. 20(a) and 20(b))

Description of location.- The airstrip area (50 by 400 ft) was part of a fairway of the golf course. It is located east of Hutchinson Road, north of Winchester Road, and 300 yards west of Mystic Street, all in Arlington south of the Winchester-Arlington town line.

Bordering the golf course in all directions except the northwest are upper-middle- to high-income homes and estates. The golf course extends in a northwesterly direction beyond the airstrip fairway, a distance of 1600 yards.

The homes to the south and southeast of the southern end of the airstrip were the closest (approximately 50 yd) to the noisiest part of the flight path.

The nearest large shopping center is Arlington, which is 2300 yards to the south of the airstrip. Figure 20(a) is a photograph of the site and figure 20(b) is a map of the surrounding area.

Flight operation.- Only one operation was made at this site (June 13, 1949) since simulated landings over the golf course bothered the golfers. Before the activity was curtailed 26 simulated landings had been made in 45 minutes.

Results.- No complaints were made from the surrounding high-income residential area during this test, as noted in table XI.

Staff evaluation.- At other test sites in this type of neighborhood if any reaction was forthcoming it was almost immediate. The fact that no complaints were made gives some preliminary indication that the noise level of the modified Cub would not be disturbing in this area.

DEMONSTRATION SITES

Brighton - Metropolitan District Commission Park

(Figs. 12(a) and 12(b))

The descriptive details of the Brighton site are given in the section "Neighborhood-Reaction Test Sites." The airstrip was used for demonstrations on two occasions and the adjacent race track was used once prior to the clearing of the airstrip.

(1) The first demonstration was on Monday, December 15, 1947, for members of the Massachusetts Recess Commission on Aviation, other public officials, and a varied group of interested and disinterested witnesses (requested to come for unbiased evaluation). The flights were simulated landings approximately 10 feet over the ground inside the race-track oval.

During this demonstration Dr. A. G. Engelbach, the Director of the Mount Auburn Hospital (on map, fig. 12(b), as Cambridge Hospital prior to change of name), the nursing staff, and a group of orderlies were requested to post themselves at open windows nearest the river to determine whether the ARF Stinson could be heard in the hospital. Exhibit 2 shows their approval.

Questionnaires (see exhibit 3) were distributed to all the witnesses at the demonstration and collected thereafter. All 72 questionnaires were answered "A" and "Yes."

(2) The second demonstration was on October 7, 1948, for the National Association of State Aviation Officials and a number of local public officials. It was made at the request of Mr. Crocker Snow, Director of the Massachusetts Aeronautics Commission, who also, after the demonstration, sent letters to the NASAO witnesses requesting their opinions and confirmation of the results for the Foundation. The letters from these State aviation officials were 100 percent in approval of the reduced noise level of the modified airplanes.

(3) The third demonstration was on Sunday, November 14, 1948. Station WBZ-TV, Boston, located adjacent to the site, presented a special telecast of the Foundation's members and airplanes and a discussion of the purposes of the research with actual flights of the airplanes (visual and audio) as a "Public Service Presentation."

The effectiveness of the "quieting" on the experimental airplanes was decidedly noticeable on the audio circuit of the television sets.

Many favorable comments were received both by WBZ management and by the Foundation, attesting widespread public interest in the elimination of aircraft noise nuisance.

Cambridge - M.I.T. Athletic Field (Figs. 21(a) and 21(b))

The airstrip area (50 by 500 ft) is a part of an open athletic field at M.I.T. It is bounded on the immediate north by the main athletic area, athletic buildings, and a large industrial area. To the east, along Massachusetts Avenue, are a group of dormitories and on the far side is the Institute proper, which is approximately 500 yards from the site. Seventy yards to the south, on Memorial Drive, are dormitories, apartment houses, and restaurants and beyond the highway is the Charles River. Starting 50 yards west of the site is an M.I.T. married students' "Veteran's Village" housing 276 families in single, duplex, and multi-unit buildings. This area extends approximately 400 yards west, and beyond it is an industrial area.

Memorial Drive which parallels the site to the south is used by pleasure vehicles only and Massachusetts Avenue, east of the site, by general traffic. Since the area to the north is industrial and has heavy truck traffic, the residents around this site are conditioned to a higher noise level than was true of most of the other sites.

The nearest shopping center is Central Square, Cambridge, which is approximately 1100 yards to the north of the airstrip.

The direction of take-off was west toward and over the Veteran's Village at an altitude of approximately 150 feet, the airplane turning left to the river when 200 feet had been attained. Figure 21(a) is a photograph of this site and figure 21(b) is a map of the surrounding area.

On October 13, 1948, both the ARF Stinson and the ARF Cub were flown (10 passes) for the Massachusetts Institute of Technology staff and on October 29 demonstration flights (7 passes) using the ARF Cub were arranged for representatives of the British Air Ministry. On both occasions all comments were favorable. No complaints were received from the adjacent residential areas.

Waltham - Murphy General Hospital (Figs. 22(a) and 22(b))

The airstrip area (50 by 400 ft) was part of an open athletic field area within the grounds of the (Army) Murphy General Hospital which is southwest of Trapelo Road and southeast of Forest Road.

Seventy-five yards to the east of the airstrip area was the central part of the hospital laid out as many individual wards. Sixty yards to the south were the mental and other wards. In the southwest corner was a fire station and across a street (100 yd) to the west were many small homes of hospital personnel. The nurses' and many other permanent barracks were 20 yards to the north and northeast.

The take-off was between the mental ward and the fire station over the overhead power lines.

On June 3 the ARF Cub, configuration 1, was flown for 1 hour and 36 low passes were made (5 to 10 ft off the ground). Neither the patients nor the hospital personnel complained although they were specifically instructed by the Commanding Officer to do so if the noise bothered them at all. It was a warm day and the fact that the airplane was acceptable even with the hospital windows open is noteworthy.

MISCELLANEOUS

Canton-Norwood

During the testing program of the modified and unmodified Stinsons (reference 1) in the vicinity of the Canton-Norwood, Mass., airports several objections, mostly of an inquiring nature, were made concerning the activity.

Most emphatic and demanding objections to stop the testing of the relatively noisy modified and unmodified pusher-type amphibians were voiced by the neighborhood surrounding the Norwood airport during that program (reference 2).

The Norwood airport was used by the U. S. Navy during World War II and has been in continuous use by Wiggins Airways for training purposes and larger-scale commercial activities.

The objections were so strenuous that Mr. Joseph Garside, President of Wiggins Airways and also acting as Director of Operations of the Foundation, had to release a statement to the local newspapers explaining the research program and requesting the neighbors' indulgence.

The fact that the neighbors accustomed to an active airport reacted in such a clamorous manner tends to confirm the observation that when the noise level is increased even in a "conditioned" neighborhood, the people will object quickly.

Bedford Air Show (Sept. 18-19, 1948)

The modified Stinson was flown as a feature attraction in the U. S. Air Force Air Show at Hanscom Airport, Bedford, Mass.

The attendance was between 110,000 and 125,000 people; however, high-powered aircraft were flying in the general area during the scheduled "quiet" Stinson demonstrations, therefore the airplane was exhibited under very unfavorable conditions.

The control-tower operator at the field announced the flights of the modified Stinson and narrated a thumbnail sketch of the Foundation and the research activities.

Approximately 1500 spectators voiced their approval to the Foundation staff and requested knowledge as to when and/or where they could buy such aircraft.

Providence Air Show (Oct. 12, 1948)

The modified Stinson and Cub were flown in comparison with standard stock models in a noise demonstration at the Theodore Francis Green Airport, Hillsgrove, R. I.

All four airplanes were flown around the field with the standard Stinson first, followed by the quieted Stinson, then the standard Cub, followed by the modified Cub. After take-off the airplanes circled the field and swooped low over the clear roped-off area next to the hangars. They passed by at about 100-foot altitude directly in front of the spectators' area.

The airport manager had, by using a public-address system, quieted the crowd down to a whisper and "all ears" in anticipation of witnessing these "airplanes of the future" with comments such as "you won't believe it till you hear it."

When the airplanes came by, the quieting effect was extremely apparent and the crowd spontaneously applauded both quieted airplanes when they passed and later when they landed.

Sound Levels Compared with Familiar Sounds

Figure 23 is included to assist in judging the results of this research. This figure presents a comparison of the measured sound levels of the standard and modified airplanes with the levels of typical noise sources.

CONCLUSIONS

In drawing conclusions from the data presented, it should be realized that complaints and responses to interviews are, to a considerable extent, subjective.

In order to separate reactions to noise from reactions to other features of airplane flight on a truly scientific basis, an elaborate program designed and controlled by experimental psychologists would be required. Such a program would have been beyond the budget and time limitations of this project. The tests reported herewith, therefore, must be considered exploratory in character and conclusive only in a limited sense.

Bearing these limitations in mind, the following conclusions seem justified.

1. Reduction in noise reduces the number of complaints in a given situation. Whether this reduction is primarily due to reduced noise per se or to the fact that fewer people notice the operation has not been definitely established. In either case, it would seem that reduced noise levels are highly desirable from a neighborhood point of view.

2. Other complaints against aircraft, that is, fear of their presence, fear of low flying, and fear of property devaluation, appear to be more frequent when noise attracts attention and sometimes are reported as noise objections. When a quieted airplane is involved, these remaining objections are more clearly defined.

3. Greatly reduced noise sometimes leads people to think an airplane is in trouble and about to make a forced landing. If quiet airplanes become numerous, this factor will probably disappear.

4. Apparently, the degree of noise reduction attained by the modified aircraft did produce significantly fewer recorded objections. Whether the difference in acceptability of standard and modified aircraft would continue over a long period of steady-flight operation was not ascertained. If the difference between reactions to the standard and quieted airplanes can be presumed to continue as in the exploratory tests, the degree of external noise reduction incorporated in the modified airplanes should lead to a significant reduction in public objection to neighborhood landing areas.

Aeronautical Research Foundation
Boston, Mass., May 5, 1950

REFERENCES

1. Beranek, Leo L., Elwell, Fred S., Roberts, John P., and Taylor, C. Fayette: Experiments in External Noise Reduction of Light Airplanes. NACA TN 2079, 1950.

2. Roberts, John P., and Beranek, Leo L.: Experiments in External Noise Reduction of a Small Pusher-Type Amphibian Airplane. NACA TN 2727, 1952.

TABLE I

STATISTICS OF AIRPLANES USED IN NEIGHBORHOOD-

REACTION TESTS

Airplane	Figure	Number of propeller blades	Type of propeller blade	Propeller diameter (in.)	Propeller pitch setting at 3/4 station (deg)	Engine	Ratio of propeller speed to engine speed	Propeller tip speed (ft/sec)	Engine power (cruising) (hp)	Crankshaft speed (cruising) (rpm)	Muffler	Peak noise levels (1)
ARF Cub (configuration 1)	1	4	Two-piece wooden	80	15 (fixed)	Geared	0.632	474	45	2150	Ejector	57
CAA Cub (configuration 2M)	3(a)	2	Wooden	72	14 (fixed)	Direct-drive	1.00	628	44	2000	Maxim	62
CAA Cub (configuration 2U)	3(b)	2	Wooden	72	14 (fixed)	Direct-drive	1.00	628	44	2000	None	69
ARF Stinson (configuration 3)	5	4	Wooden	76	25 (fixed)	Geared	.632	476	96	2250	Maxim	63
Standard Cub (configuration 4)	6	2	Wooden	72	14 (fixed)	Direct-drive	1.00	628	44	2000	Standard	66

[1]At 500-ft altitude, cruising power, and 40-db weighting. Each number is an average of four readings.

TABLE II

TESTS AT ARLINGTON SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings[1]	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
6-19-49	Sun.	0700-0800 a.m.	1 hr	35	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
6-29-49	Wed.	0600-0700 p.m.	1 hr	35	ARF Cub (configuration 1)	1	0	0	1	0	0	0	1	1
7-2-49	Sat.	0700-0815 a.m.	1 hr 15 min	46	ARF Cub (configuration 1)	2	1	0	2	1	0	0	3	4
7-3-49	Sun.	0700-0815 a.m.	1 hr 15 min	43	Standard Cub (configuration 4)	8	4	9	2	1	0	0	12	16
7-10-49	Sun.	0700-0800 a.m.	1 hr	34	Standard Cub (configuration 4)	6	1	7	0	0	0	0	7	23
7-24-49	Sun.	0700-0800 a.m.	1 hr	36	ARF Cub (configuration 1)	0	1	0	1	0	0	0	1	24
7-26-49	Tues.	0715-0800 a.m.	45 min	29	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	24
Totals			7 hr 15 min	258		17	7	16	6	2	0	0	24	24

[1]Simulated landings.

TABLE III

TESTS AT BRIGHTON SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
12-19-48	Sun.	0700-0915 a.m.	2 hr 15 min	30	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
12-27-48	Mon.	0630-1015 a.m.	[a]3 hr 20 min	50	ARF Cub[b] (configuration 1)	0	0	0	0	0	0	0	0	0
12-28-48	Tues.	0600-1100 a.m.	[a]4 hr 30 min	80	ARF Cub[b] (configuration 1)	0	0	0	0	0	0	0	0	0
1-20-49	Thurs.	0230-0430 p.m.	2 hr	17	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
1-21-49	Fri.	[c]0600-0730 a.m.	1 hr 30 min	10	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
1-22-49	Sat.	[c]0600-0740 a.m.	1 hr 40 min	15	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
1-23-49	Sun.	0600-1030 a.m.	[a]4 hr	55	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	None
Test totals			19 hr 15 min	257										
Add for previous demonstrations, TV show, and TV interception			6 hr 30 min	63										
Totals			25 hr 45 min	320		0	0	0	0	0	0	0	0	None

[a]Time out to refuel.

[b]On skiis.

[c]Discontinued because of snow.

TABLE IV

TESTS AT BROCKTON SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
2-16-49	Wed.	0230-0310 p.m.	40 min	13	ARF Cub (configuration 1)	52	0	0	37	15	0	0	52	52
2-16-49	Wed.	0350-0440 p.m.	50 min	22	ARF Cub (configuration 1)	26	0	0	18	8	0	0	26	78
2-18-49	Fri.	[a]0930-1030 a.m.	1 hr	20	ARF Cub (configuration 1)	13	0	0	7	6	0	0	13	91
Totals			2 hr 30 min	55		91	0	0	62	29	0	0	91	91

[a]Stopped. See text.

TABLE V

TESTS AT CANTON SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
10-28-48	Thurs.	0200-0215 p.m.	15 min	3	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
11-18-48	Thurs.	0700-1000 a.m.	3 hr	35	ARF Stinson (configuration 3)	0	0	0	0	0	0	0	0	0
11-26-48	Fri.	0630-0740 a.m.	1 hr 10 min	15	ARF Stinson (configuration 3)	0	0	0	0	0	0	0	0	0
12-24-48	Fri.	0700-0940 a.m.	2 hr 40 min	40	ARF Cub[a] (configuration 1)	0	0	0	0	0	0	0	0	0
1-3-49	Mon.	0600-0705 p.m.	1 hr 5 min	17	ARF Cub[a] (configuration 1)	0	0	0	0	0	0	0	0	0
6-11-49	Sat.	[b]0700-0800 a.m.	1 hr	30	Standard Cub (configuration 4)	3	2	4	1	0	0	0	5	5
6-14-49	Tues.	[b] [c]0700-0715 a.m.	15 min	7	Standard Cub (configuration 4)	1	1	2	0	0	0	0	2	7
Totals			9 hr 25 min	147		4	3	6	1	0	0	0	7	7

[a]On skiis.

[b]Moved to alternate strip.

[c]Stopped at owner's demand.

TABLE VI

TESTS AT MEDFORD SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings[1]	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
8-24-49	Wed.	0200-0300 p.m.	1 hr	22	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
8-25-49	Thurs.	1030-1130 a.m.	1 hr	22	ARF Cub (configuration 1)	1	0	0	1	0	0	0	1	1
8-26-49	Fri.	0700-0800 a.m.	1 hr	22	ARF Cub (configuration 1)	1	0	0	1	0	0	0	1	2
8-31-49	Wed.	0100-0200 p.m.	1 hr	22	CAA Cub (configuration 2M)	1	0	0	0	1	0	0	1	3
9-1-49	Thurs.	1100-1200 a.m.	1 hr	22	CAA Cub (configuration 2M)	0	1	0	0	0	0	1	1	4
9-2-49	Fri.	0700-0800 a.m.	1 hr	22	CAA Cub (configuration 2U)	1	0	1	0	0	0	0	1	5
9-2-49	Fri.	1100-1200 a.m.	1 hr	22	CAA Cub (configuration 2U)	3	0	1	1	0	0	1	3	8
9-3-49	Sat.	0700-0800 a.m.	1 hr	23	CAA Cub (configuration 2U)	5	0	4	1	0	0	0	5	13
Totals			8 hr	177		12	1	6	4	1	0	2	13	13

[1]Simulated landings.

TABLE VII

TESTS AT MILTON SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings[a]	Airplane	By telephone	In person	Noise	Low flying	Fear		Airport objection	Daily	Accumulated
											Both			
6-9-49	Thurs.	0600-0700 p.m.	1 hr	35	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
6-18-49	Sat.	0715-0800 a.m.	45 min	25	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
6-20-49	Mon.	[b]0700-0718 a.m.	18 min	10	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
6-21-49	Tues.	0630-0715 a.m.	45 min	26	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
6-21-49	Tues.	[c]0730-0745 a.m.	15 min	8	Standard Cub (configuration 4)	1	0	1	0	0	0	0	1	1
6-28-49	Tues.	0715-0800 a.m.	45 min	23	Standard Cub (configuration 4)	2	0	2	0	0	0	0	2	3
Totals			3 hr 48 min	127		3	0	3	0	0	0	0	3	3

[a]Simulated landings.

[b]Vee-belt turned over.

[c]Returned because of weather.

TABLE VIII

TESTS AT NEEDHAM SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings[a]	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
6-10-49	Fri.	1000-1030 a.m.	30 min	17	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
7-27-49	Wed.	1100-1200 a.m.	1 hr	32	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
7-27-49	Wed.	0600-0700 p.m.	1 hr	35	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
7-29-49	Fri.	0700-0800 a.m.	1 hr	36	ARF Cub (configuration 1)	1	0	[b]1	0	0	0	0	1	1
7-29-49	Fri.	0200-0300 p.m.	1 hr	35	ARF Cub (configuration 1)	7	0	[b]1	2	1	1	2	7	8
8-1-49	Mon.	1100-1200 a.m.	1 hr	35	ARF Cub (configuration 1)	3	0	[b]1	1	1	0	0	3	11
8-5-49	Fri.	1000-1115 a.m.	1 hr 15 min	30	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	11
8-5-49	Fri.	0200-0300 p.m.	1 hr	22	CAA Cub (configuration 2M)	1	0	0	0	0	1	0	1	12
8-6-49	Sat.	1000-1100 a.m.	1 hr	22	CAA Cub (configuration 2M)	0	0	0	0	0	0	0	0	12
8-8-49	Mon.	0730-0830 a.m.	1 hr	23	CAA Cub (configuration 2M)	1	0	0	0	0	1	0	1	13
8-8-49	Mon.	1220-0120 p.m.	1 hr	22	CAA Cub (configuration 2U)	4	0	2	0	0	2	0	4	17
8-9-49	Tues.	0710-0810 a.m.	1 hr	25	CAA Cub (configuration 2U)	4	0	4	0	0	0	0	4	21
Totals			11 hr 45 min	334		21	0	9	3	2	5	2	21	21

[a]Simulated landings.
[b]Same person complained.

TABLE IX

TESTS AT NEWTON SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
10-27-48	Wed.	0100-0200 p.m.	1 hr	16	ARF Cub (configuration 1)	0	5	0	0	5	0	0	5	5
10-31-48	Sun.	0745-1215 a.m.	4 hr 30 min	56	ARF Cub (configuration 1)	1	13	0	1	6	5	2	14	19
10-31-48	Sun.	[a]0200-0430 p.m.	2 hr 30 min	31	ARF Cub (configuration 1)	0	3	0	0	2	1	0	3	22
Totals			8 hr	103		1	21	0	1	13	6	2	22	22

[a]Stopped. See text.

TABLE X

TESTS AT NEWTON-BRIGHTON SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings[1]	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
8-15-49	Mon.	1015-1115 a.m.	1 hr	17	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
8-15-49	Mon.	0230-0330 p.m.	1 hr	17	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
8-17-49	Wed.	0725-0825 a.m.	1 hr	16	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	0
8-18-49	Thurs.	0200-0300 p.m.	1 hr	16	CAA Cub (configuration 2M)	0	0	0	0	0	0	0	0	0
8-20-49	Sat.	0700-0800 a.m.	1 hr	17	CAA Cub (configuration 2M)	0	0	0	0	0	0	0	0	0
8-22-49	Mon.	1100-1200 a.m.	1 hr	17	CAA Cub (configuration 2U)	0	0	0	0	0	0	0	0	0
8-23-49	Tues.	0745-0845 a.m.	1 hr	17	CAA Cub (configuration 2U)	0	0	0	0	0	0	0	0	0
8-25-49	Thurs.	0630-0730 a.m.	1 hr	18	CAA Cub (configuration 2U)	0	0	0	0	0	0	0	0	None
Totals			8 hr	135		0	0	0	0	0	0	0	0	None

[1]Simulated landings.

TABLE XI

TESTS AT WINCHESTER SITE

Operations						Complaints								
								Classifications					Totals	
Date	Day of week	Time of day	Flight time	Number of landings[a]	Airplane	By telephone	In person	Noise	Low flying	Fear	Both	Airport objection	Daily	Accumulated
6-13-49	Mon.	[b]1000-1045 a.m.	45 min	26	ARF Cub (configuration 1)	0	0	0	0	0	0	0	0	None
Totals			45 min	26		0	0	0	0	0	0	0	0	None

[a]Simulated landings.

[b]Presence bothered golfers.

TABLE XII

COMPARISON OF TEST SITES

[Quieted includes ARF airplanes and muffled version of CAA Cub; standard includes standard Cub and unmuffled CAA Cub]

Sites	Operations						Complaints															
	Number of tests		Flight time		Number of landings		By telephone		In person		Noise		Low flying		Fear		Both		Airport objection		Total	
	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard	Quieted	Standard
Arlington	5	2	5 hr	2 hr 15 min	181	77	3	14	2	5	0	16	4	2	1	1	0	0	0	0	5	19
Brighton	12	0	25 hr 45 min	0	[a]320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Not used
Brockton	3	0	2 hr 30 min	0	[a]55	0	91	0	0	0	0	0	62	0	29	0	0	0	0	0	91	Not used
Canton	5	2	8 hr 10 min	1 hr 15 min	[a]110	[a]37	0	4	0	3	0	6	0	1	0	0	0	0	0	0	7	0
Medford	5	3	5 hr	3 hr	110	67	3	9	1	0	0	6	2	2	1	0	0	0	1	1	4	9
Milton	4	2	2 hr 48 min	1 hr	96	31	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	3
Needham	10	2	9 hr 45 min	2 hr	287	47	13	8	0	0	[b]3	6	3	0	2	0	3	2	2	0	13	8
Newton	3	0	8 hr	0	[a]103	0	1	0	21	0	0	0	1	0	13	0	6	0	2	0	22	Not used
Newton-Brighton	5	3	5 hr	3 hr	83	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winchester	1	0	45 min	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Not used
Subtotals	53	14	72 hr 43 min	12 hr 30 min	1371	311	111	38	24	8	3	37	72	5	46	1	9	2	5	1	142	39
Totals	67		85 hr 13 min		1682		149		32		40		77		47		11		6		181	

[a]Actual landings; others simulated.

[b]See table VIII and text.

Figure 1.- Various views of modified ARF Cub (configuration 1).

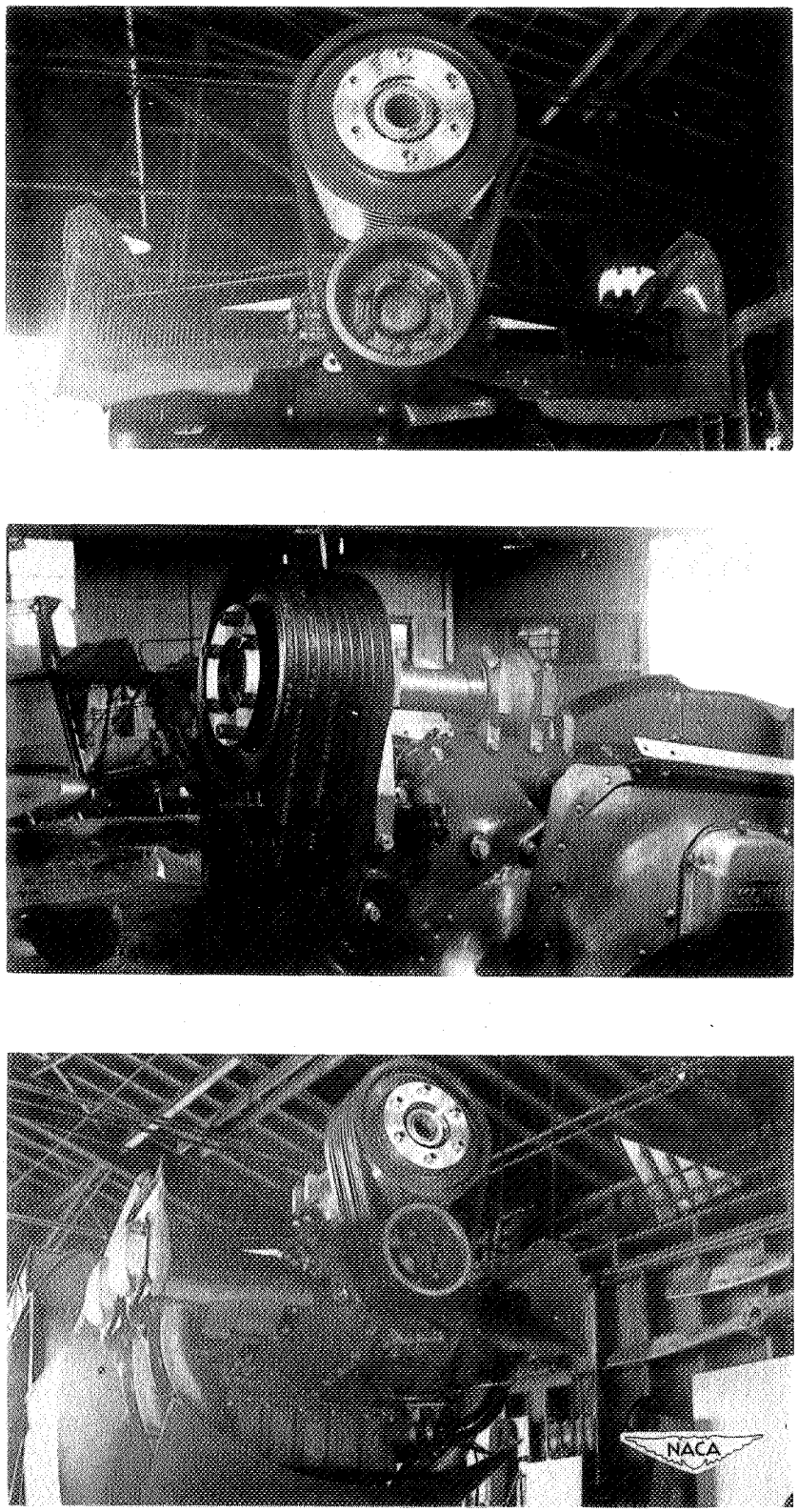
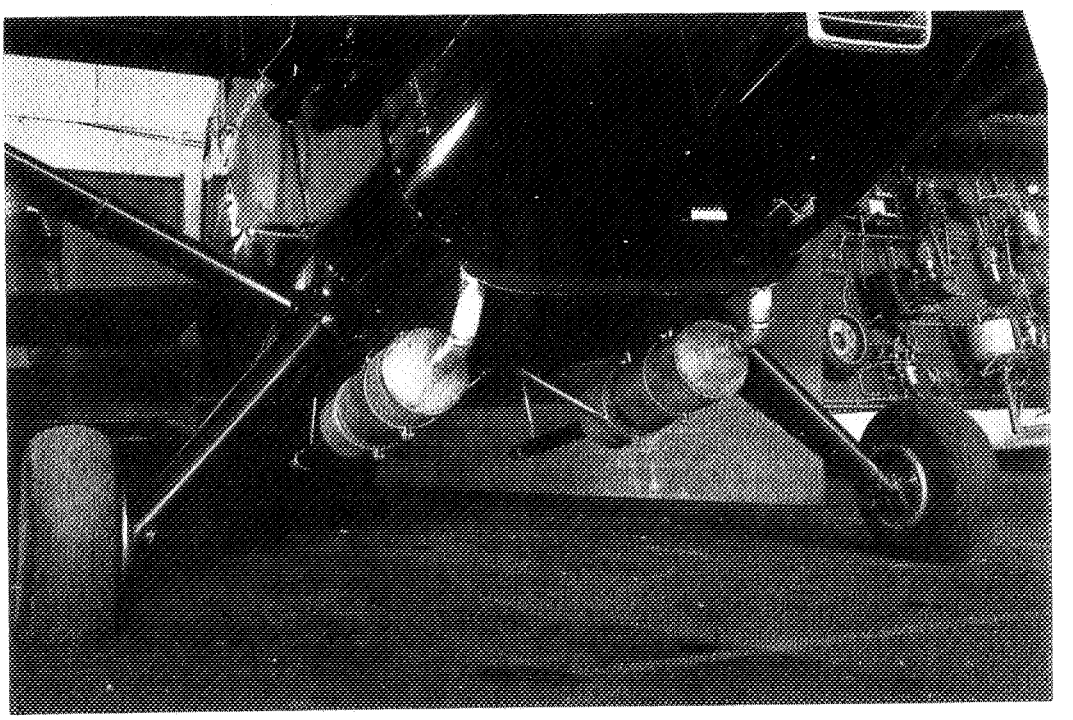


Figure 2.- Three views of vee-belt propeller drive used with engine of modified ARF Cub (configuration 1).

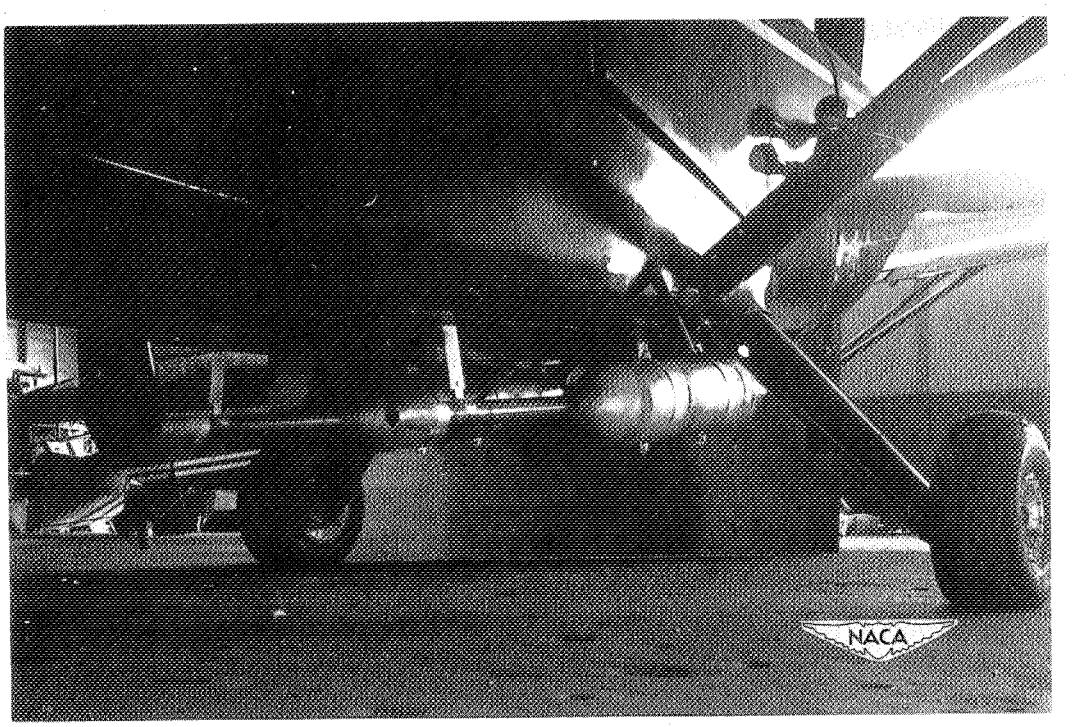
(a) Muffled (configuration 2M).

(b) Unmuffled (configuration 2U).

Figure 3.- Modified CAA Cub.



(a) Front view.



(b) Rear view.

Figure 4.- Silencers mounted on Stinson airplane (configuration 3).

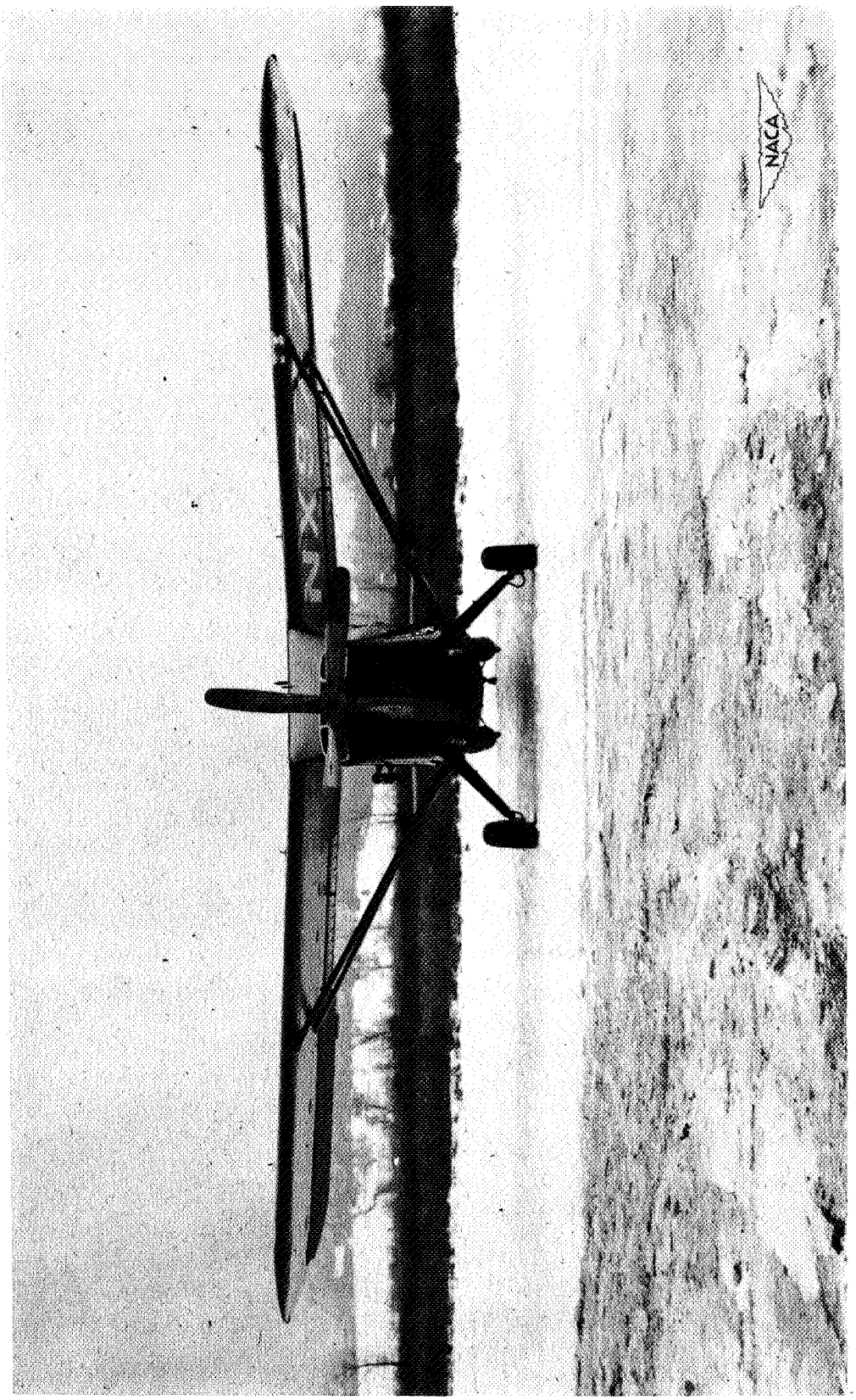


Figure 5.- ARF Stinson (configuration 3).

Figure 6.- Standard Cub (configuration 4).

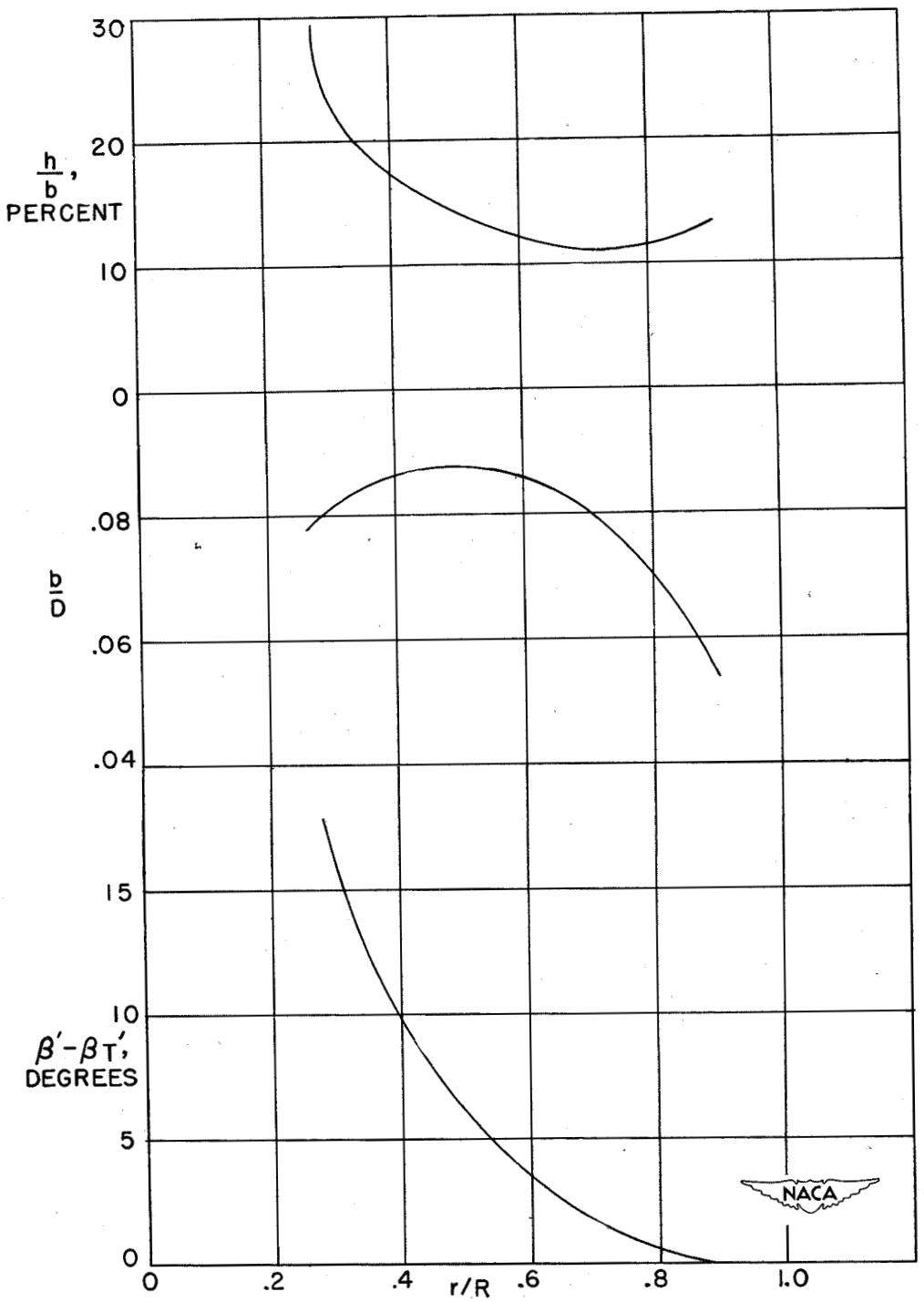


Figure 7.- Blade-form curves for four-bladed, two-piece propeller used on ARF Cub (configuration 1). D, diameter of propeller; R, tip radius; r, radius of element; b, width (chord) of element; h, maximum thickness of element; β', pitch angle of element; βT', pitch angle of tip element.

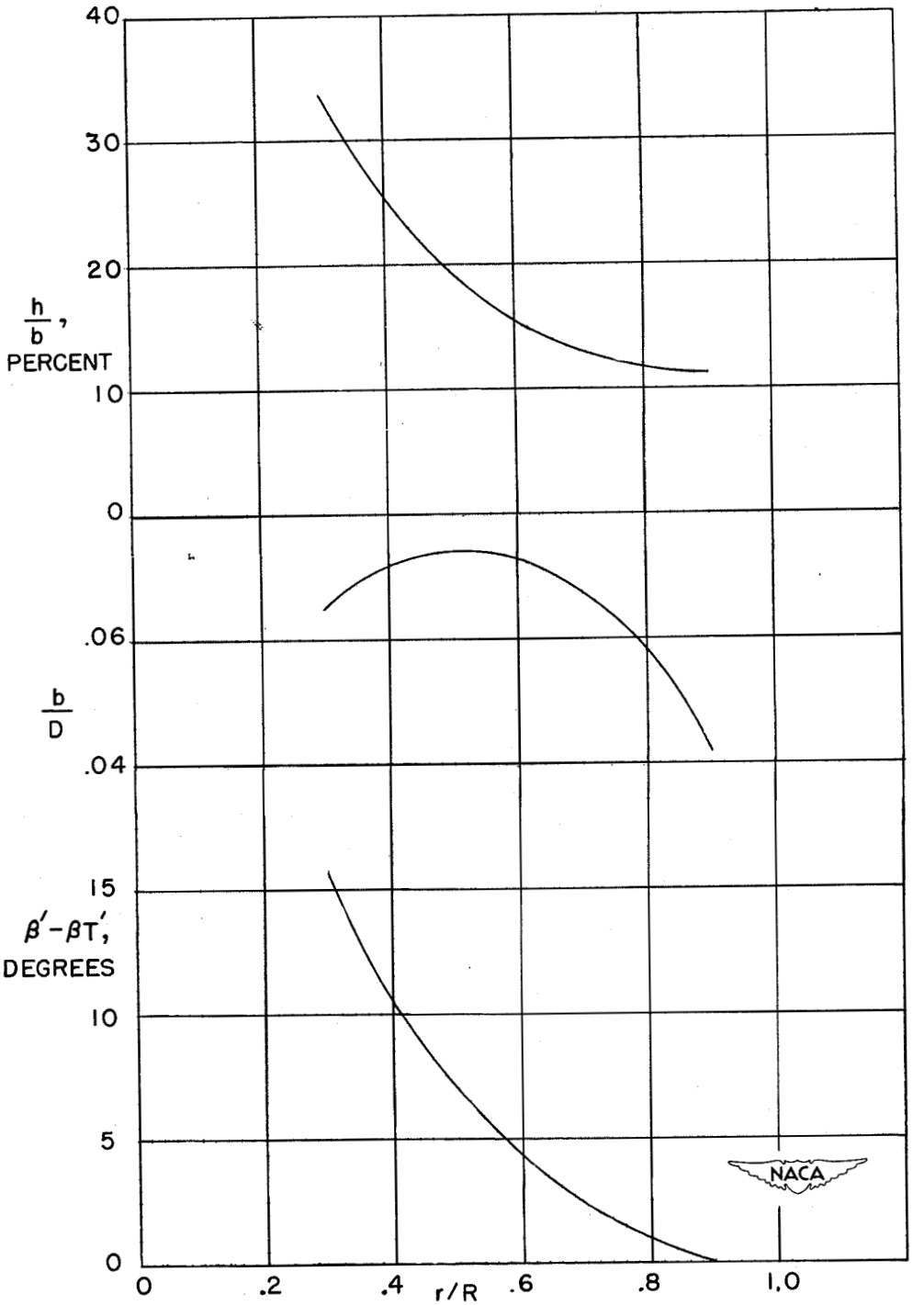


Figure 8.- Blade-form curves for propeller used on both versions of CAA Cub (configurations 2M and 2U) and on standard Cub (configuration 4). D, diameter of propeller; R, tip radius; r, radius of element; b, width (chord) of element; h, maximum thickness of element; β', pitch angle of element; βT', pitch angle of tip element.

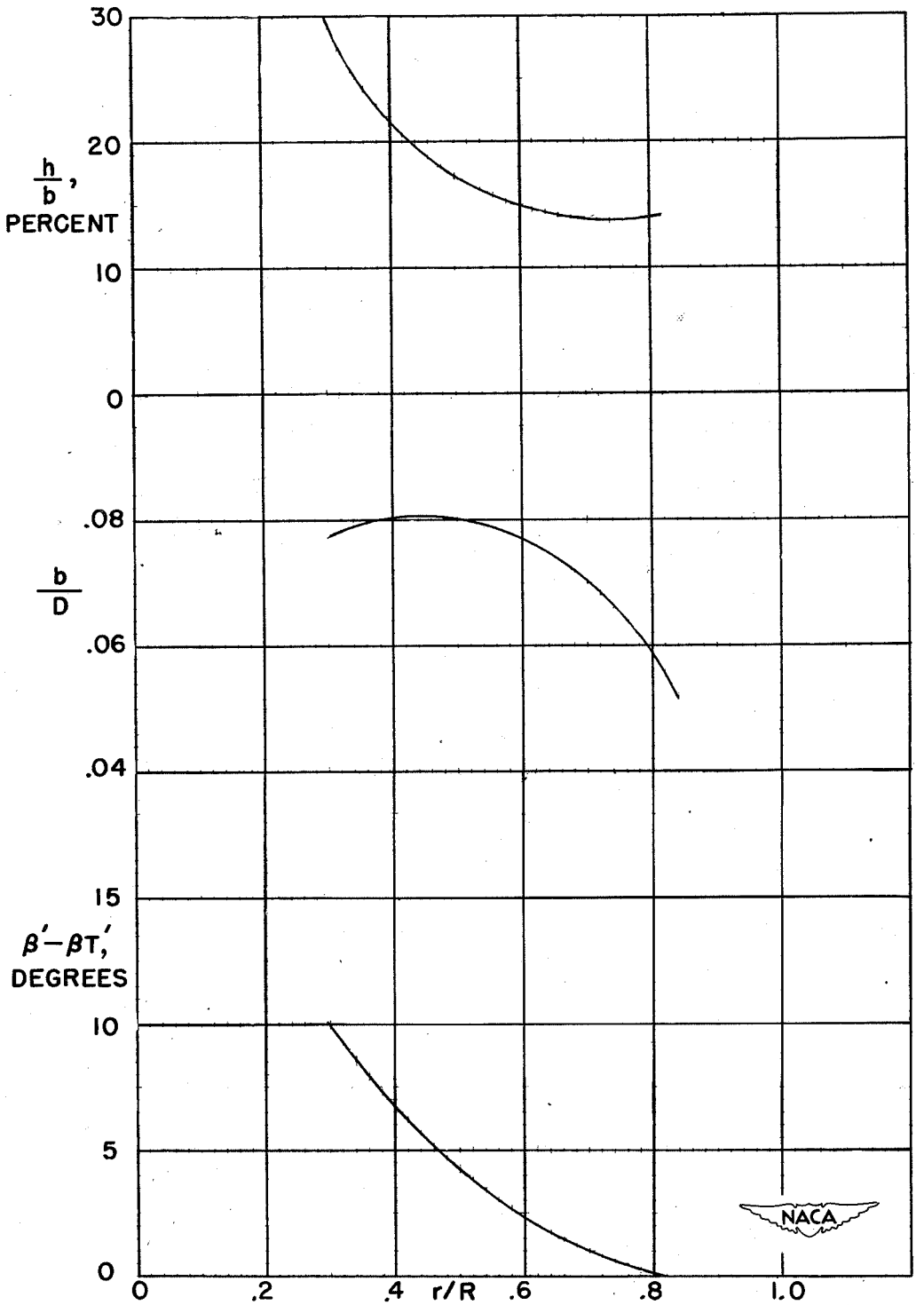


Figure 9.- Blade-form curves for four-bladed, one-piece propeller tried on CAA Cub (configuration 2M). D, diameter of propeller; R, tip radius; r, radius of element; b, width (chord) of element; h, maximum thickness of element; β', pitch angle of element; βT', pitch angle of tip element.

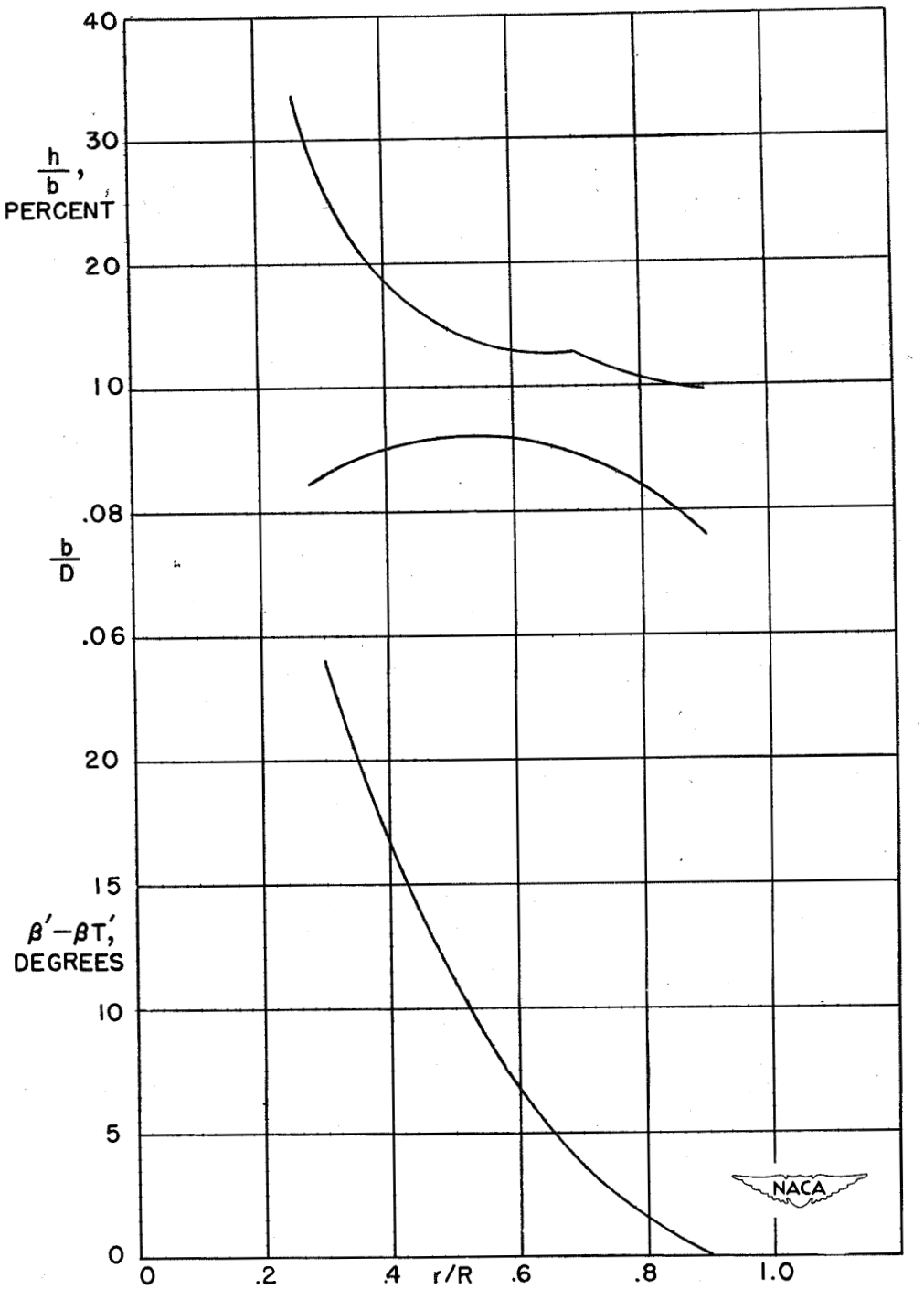
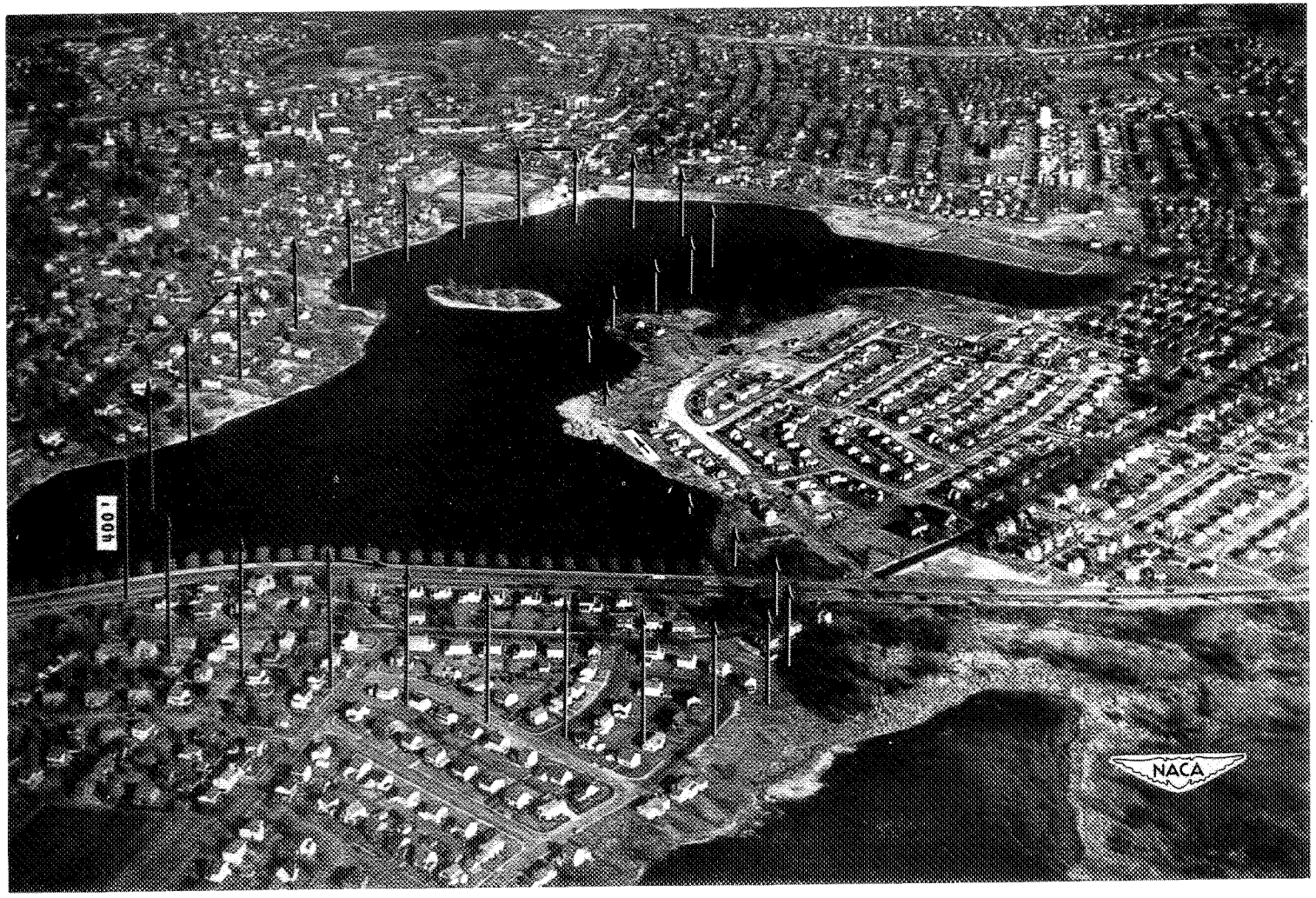
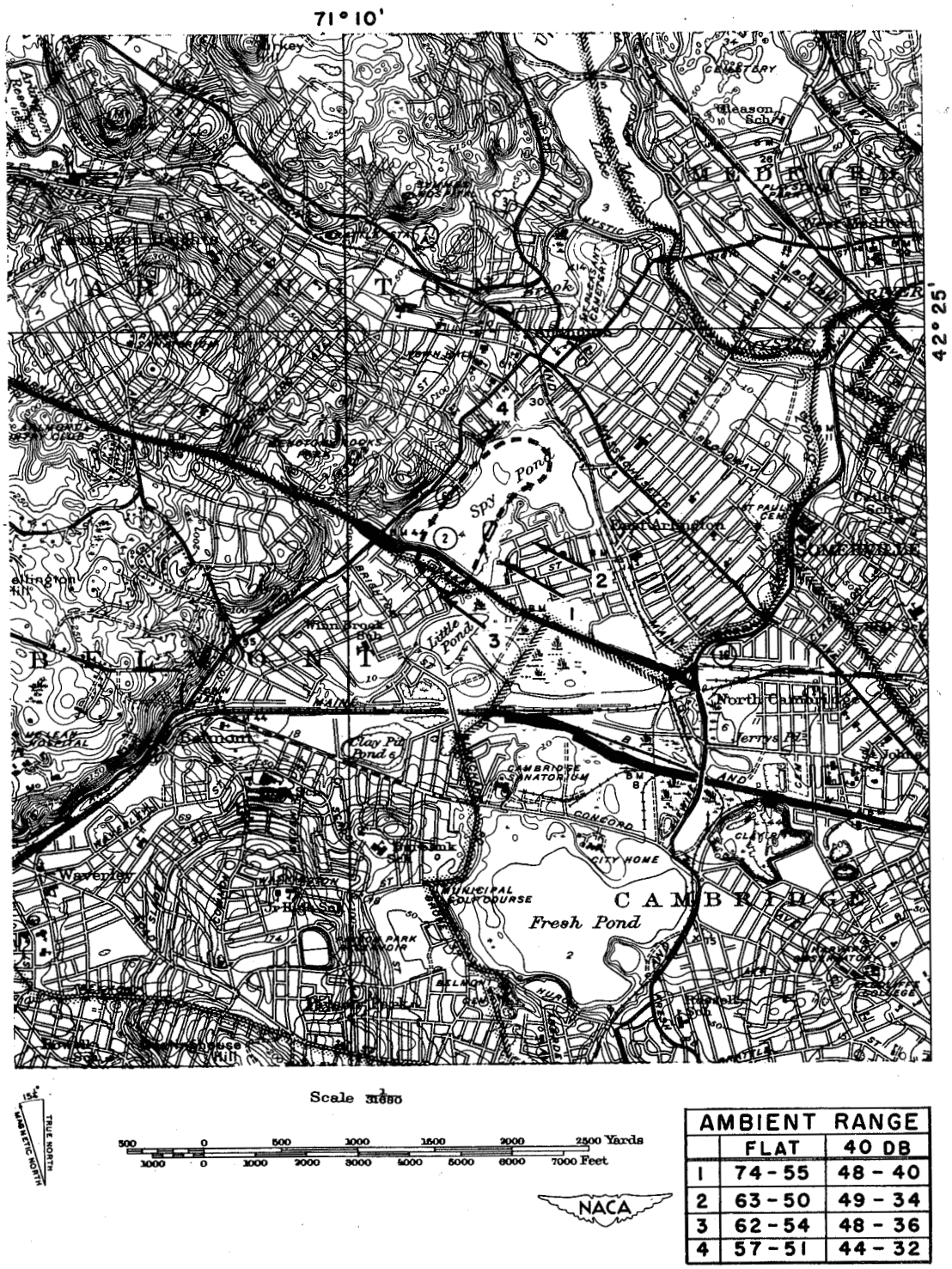


Figure 10.- Blade-form curves for four-bladed, one-piece propeller used on ARF Stinson (configuration 3). D, diameter of propeller; R, tip radius; r, radius of element; b, width (chord) of element; h, maximum thickness of element; β', pitch angle of element; βT', pitch angle of tip element.



(a) View of site with air traffic pattern superimposed.

Figure 11.- Arlington site.

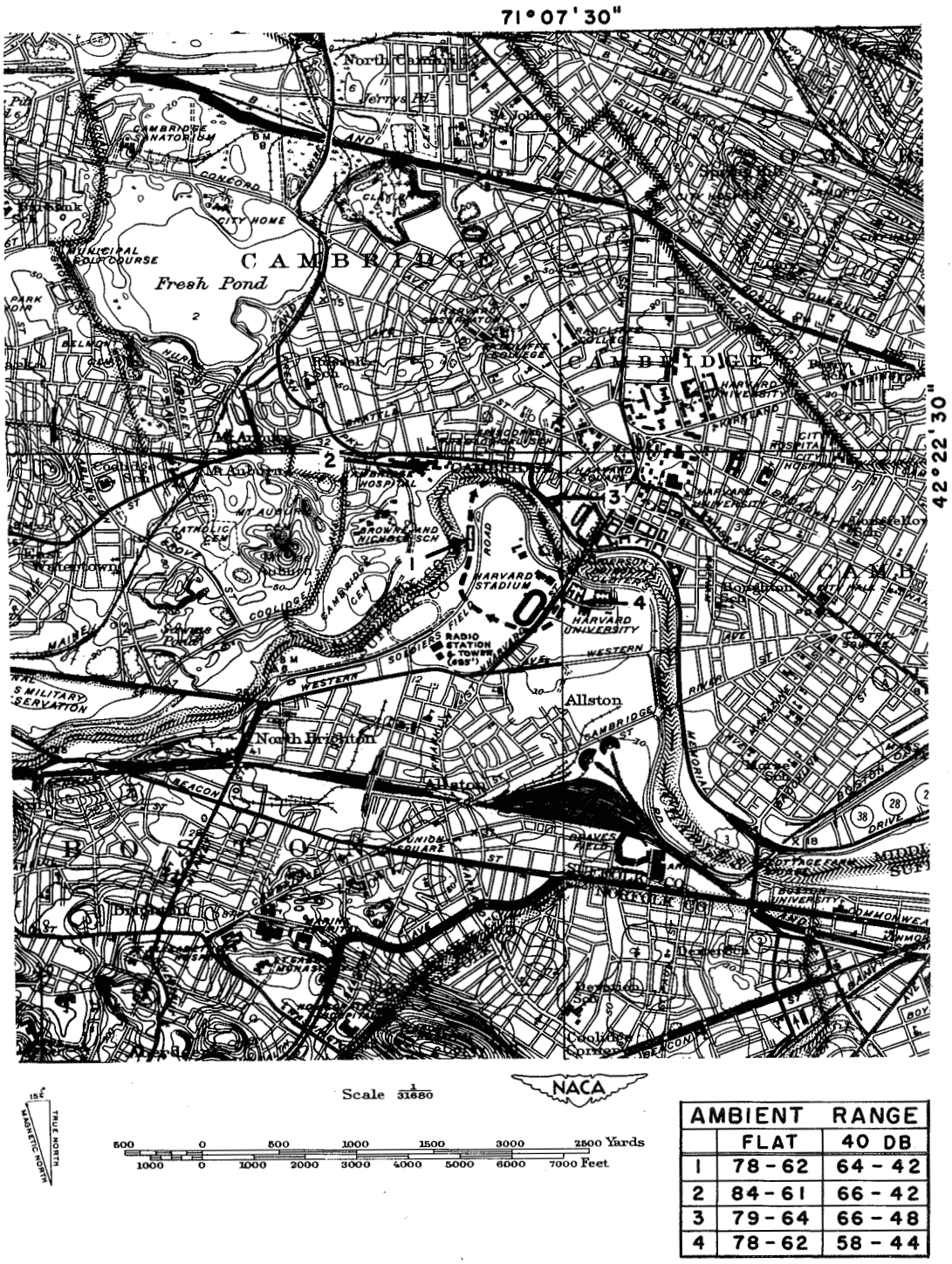


(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 11.- Concluded.

(a) View of site with air traffic pattern superimposed.

Figure 12.- Brighton site.



AMBIENT	RANGE	
	FLAT	40 DB
1	78 - 62	64 - 42
2	84 - 61	66 - 42
3	79 - 64	66 - 48
4	78 - 62	58 - 44

(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

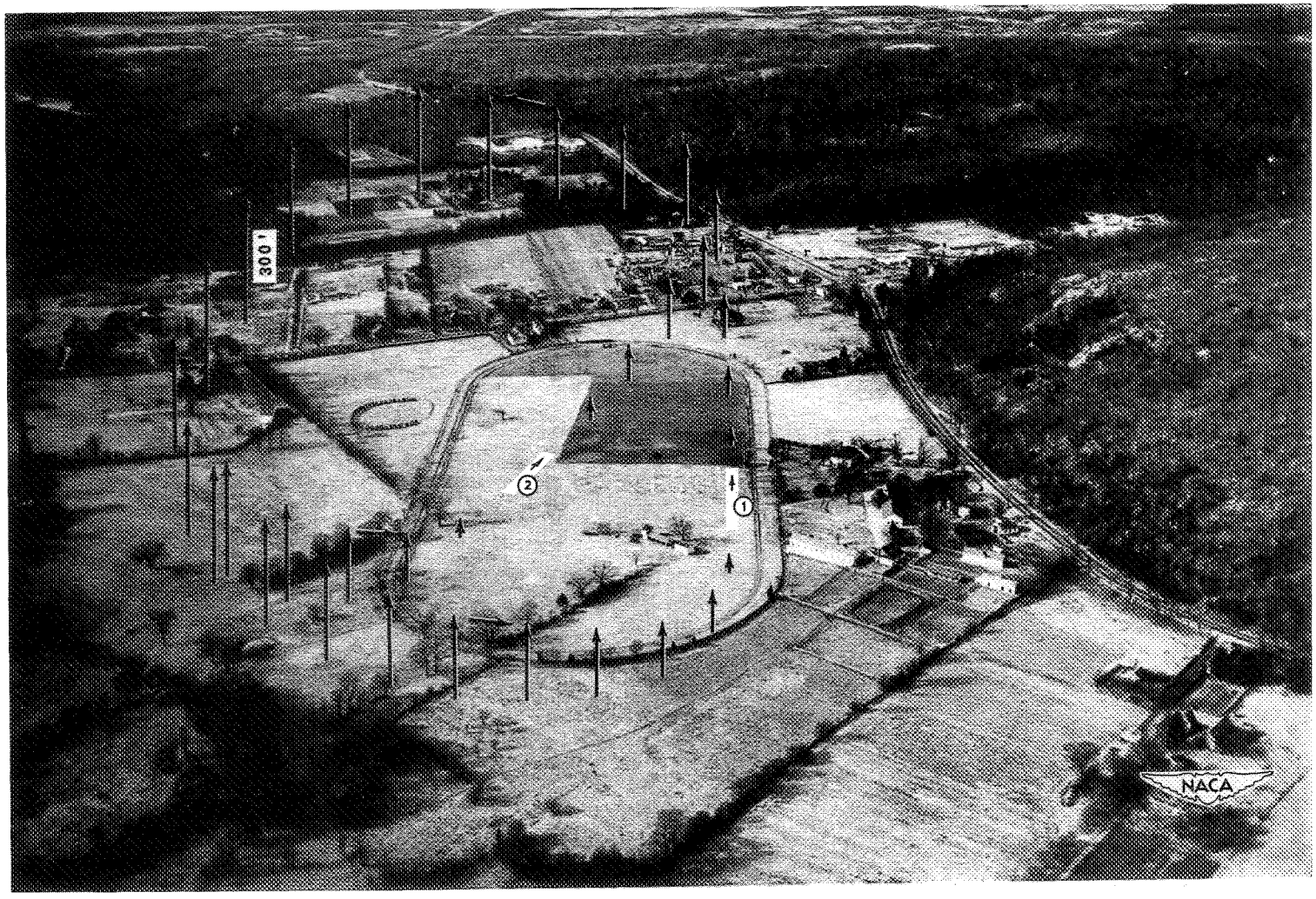
Figure 12.- Concluded.

(a) View of site with air traffic pattern superimposed.

Figure 13.- Brockton site.

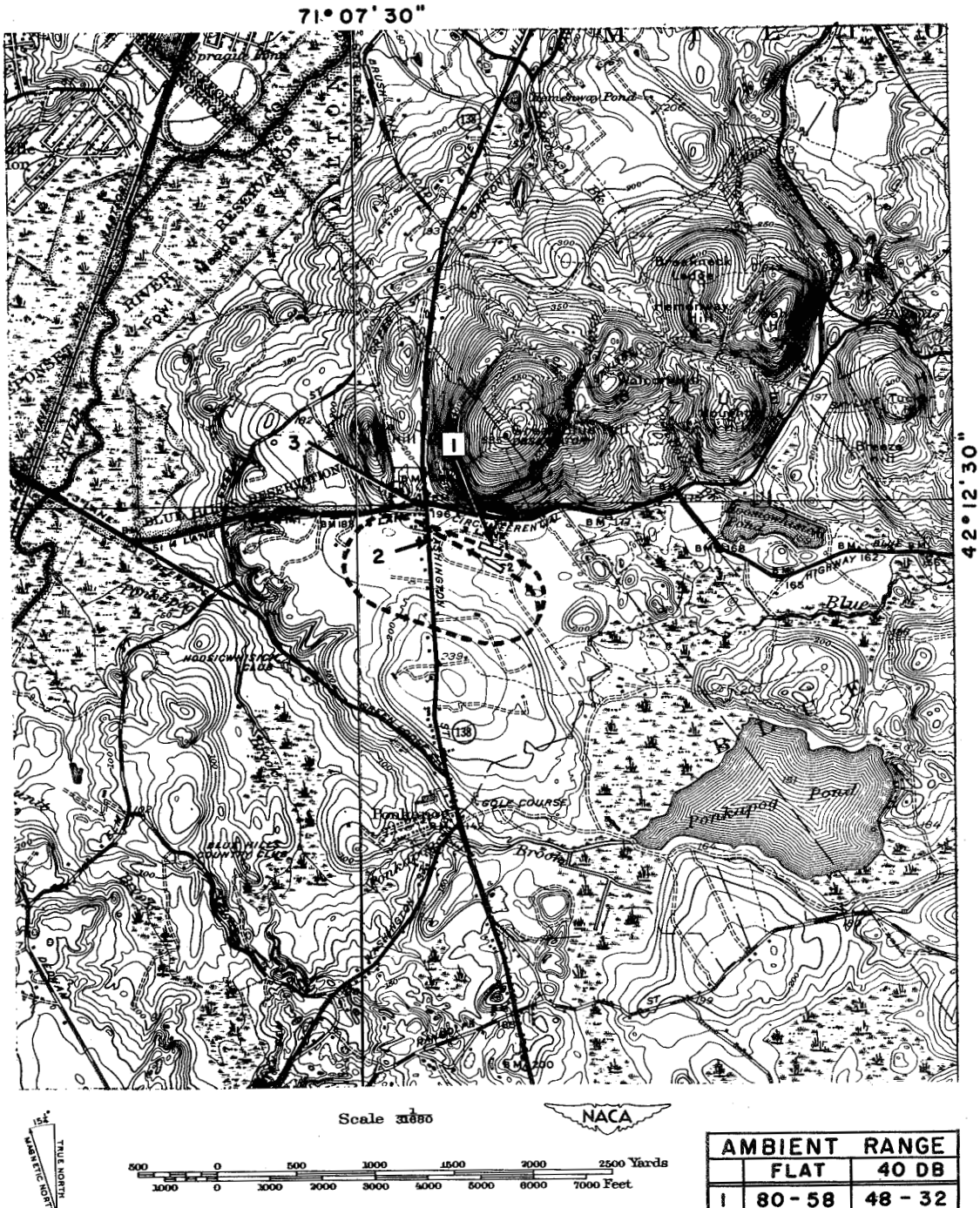
(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 13.- Concluded.



(a) View of site with air traffic pattern superimposed.

Figure 14.- Canton site.



AMBIENT	RANGE	
	FLAT	40 DB
1	80 - 58	48 - 32
2	81 - 58	62 - 41
3	73 - 56	51 - 32

(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

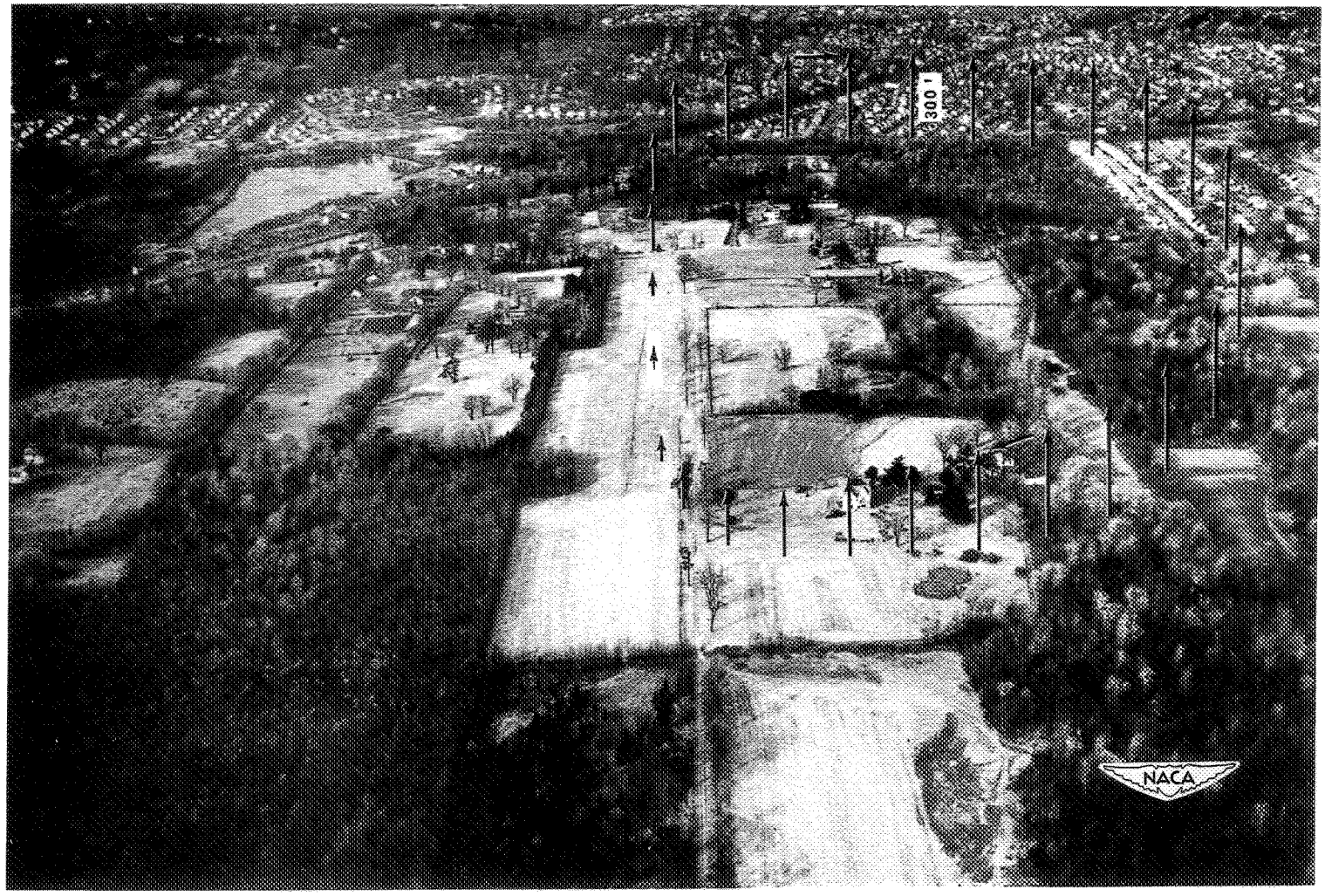
Figure 14.- Concluded.

(a) View of site with air traffic pattern superimposed.

Figure 15.- Medford site.

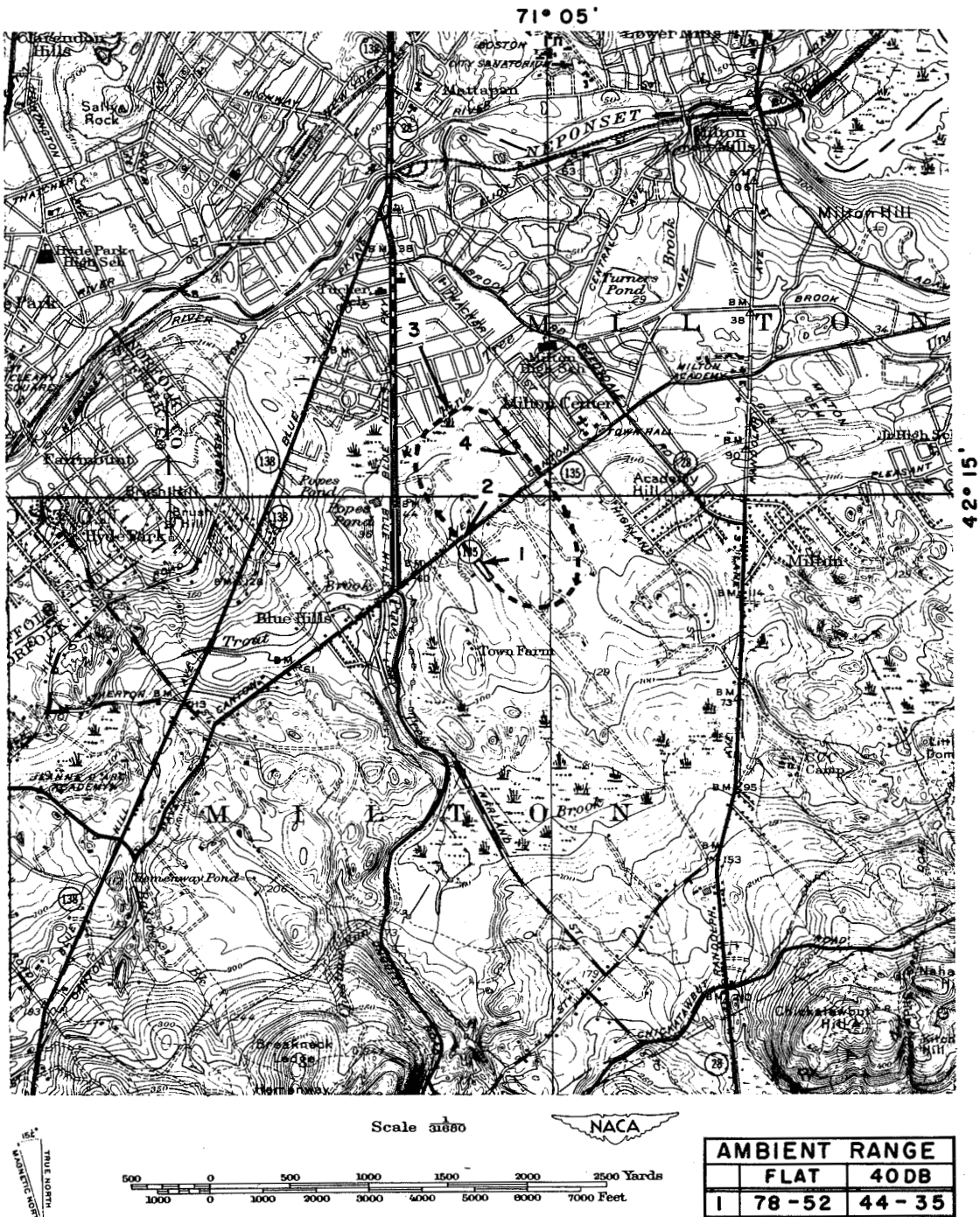
(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

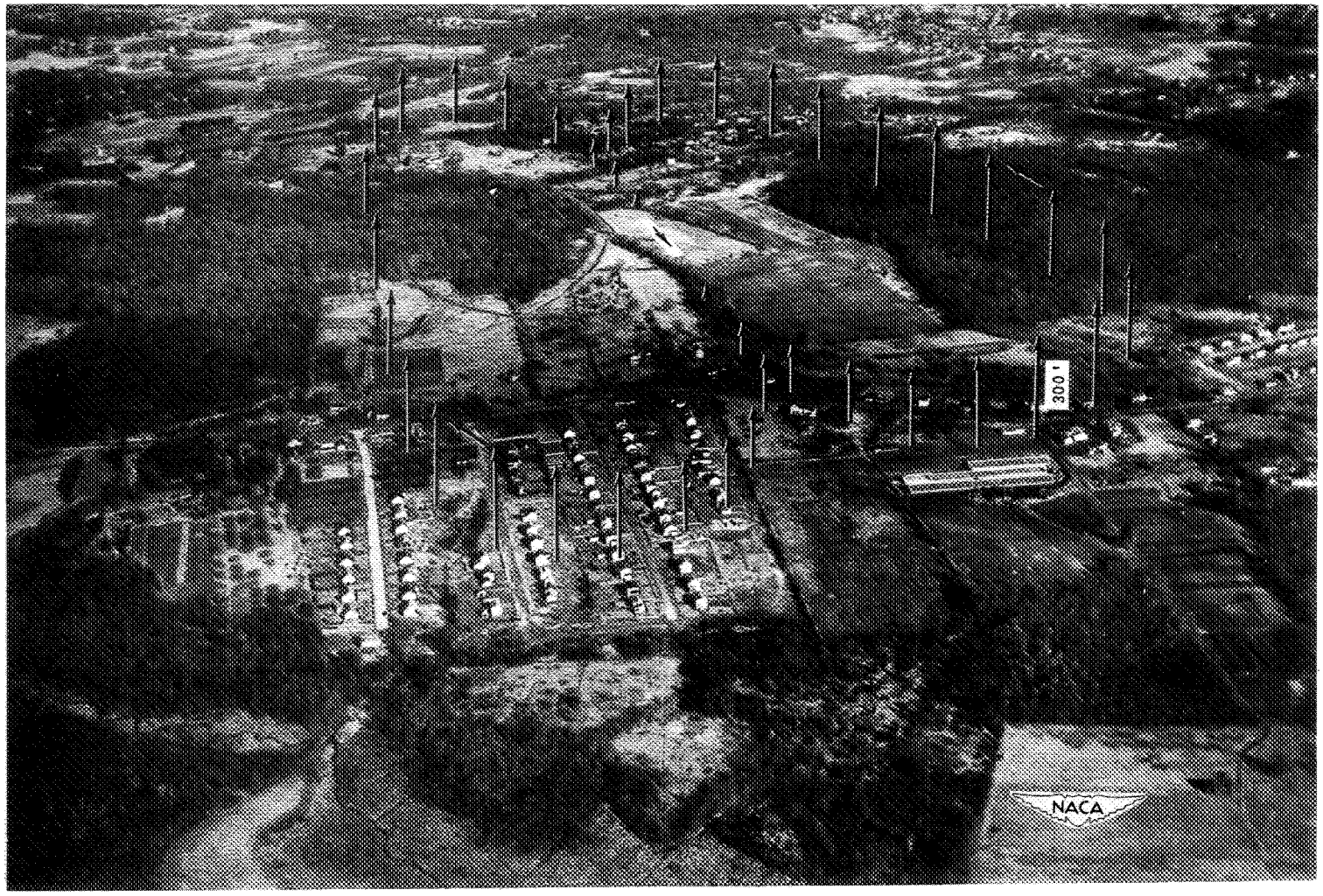
Figure 15.- Concluded.



(a) View of site with air traffic pattern superimposed.

Figure 16.- Milton site.


71° 05'
42° 15'
Scale 1/31680
NACA
500 0 500 1000 1500 2000 2500 Yards
1000 0 1000 2000 3000 4000 5000 6000 7000 Feet
TRUE NORTH
MAGNETIC NORTH
M I L T O N
Mattapan
NEPONSET
Milton Hill
Milton Center
Academy Hill
Blue Hills
Town Farm
Trout Brook
Brook
Hyde Park
Fairmount
Pope's Pond
Turner's Pond
Brush Hill
Clarendon Hills
Saltonstall Rock
Brookwood Park
Brookwood Farm
Brookwood Road
Blue Hill Parkway
Brook Road
Thacher Road
Thacher Rd.
Thacher Park
Hyde Park High Sch.
Milton High Sch.
Milton Academy
Turners Pond
Pope's Pond
Brush Hill
Blue Hills
Town Farm
Trout Brook
Brook
Hyde Park
Fairmount
Mattapan
Milton Hill
Milton Center
Academy Hill

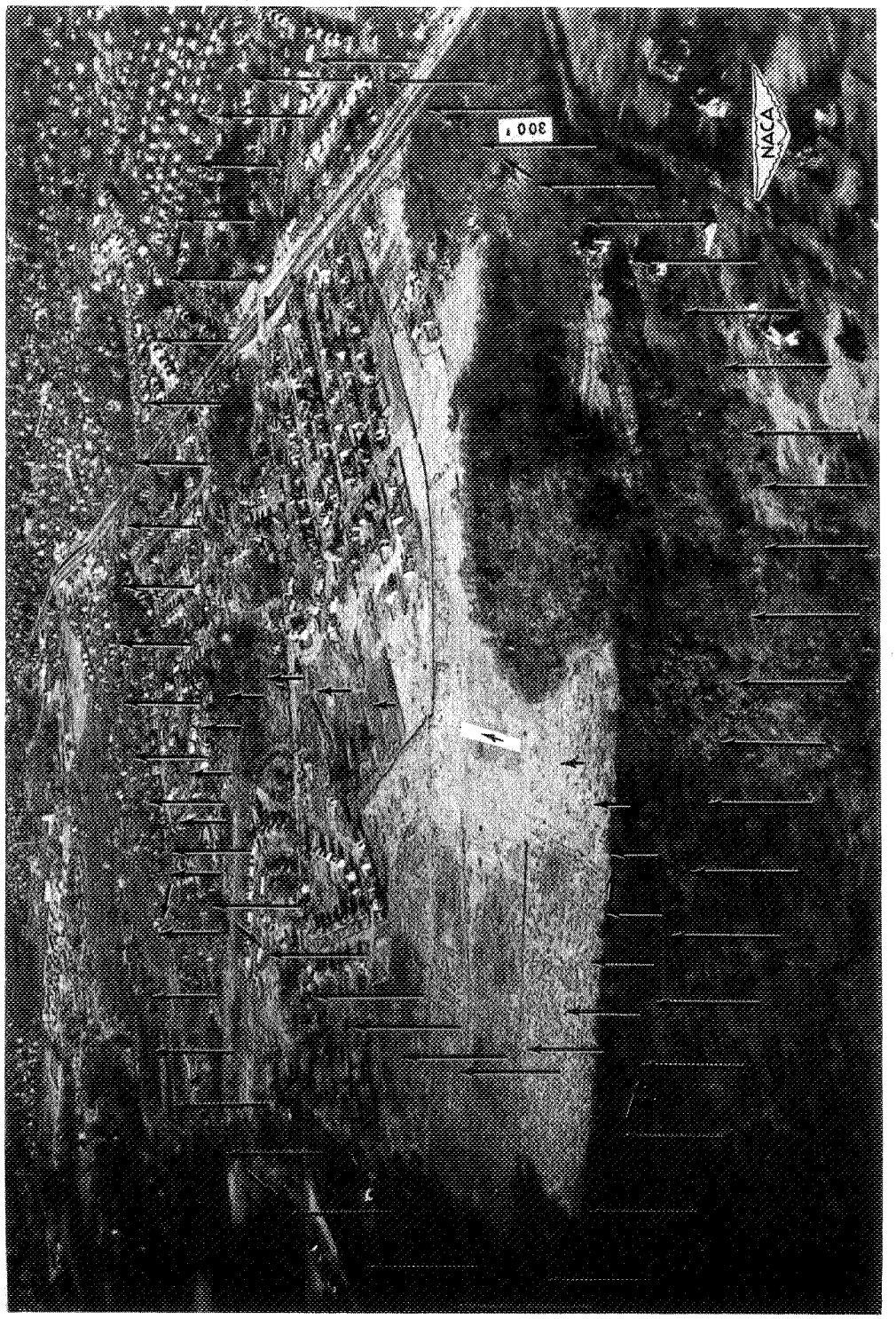


(a) View of site with air traffic pattern superimposed.

Figure 17.- Needham site.

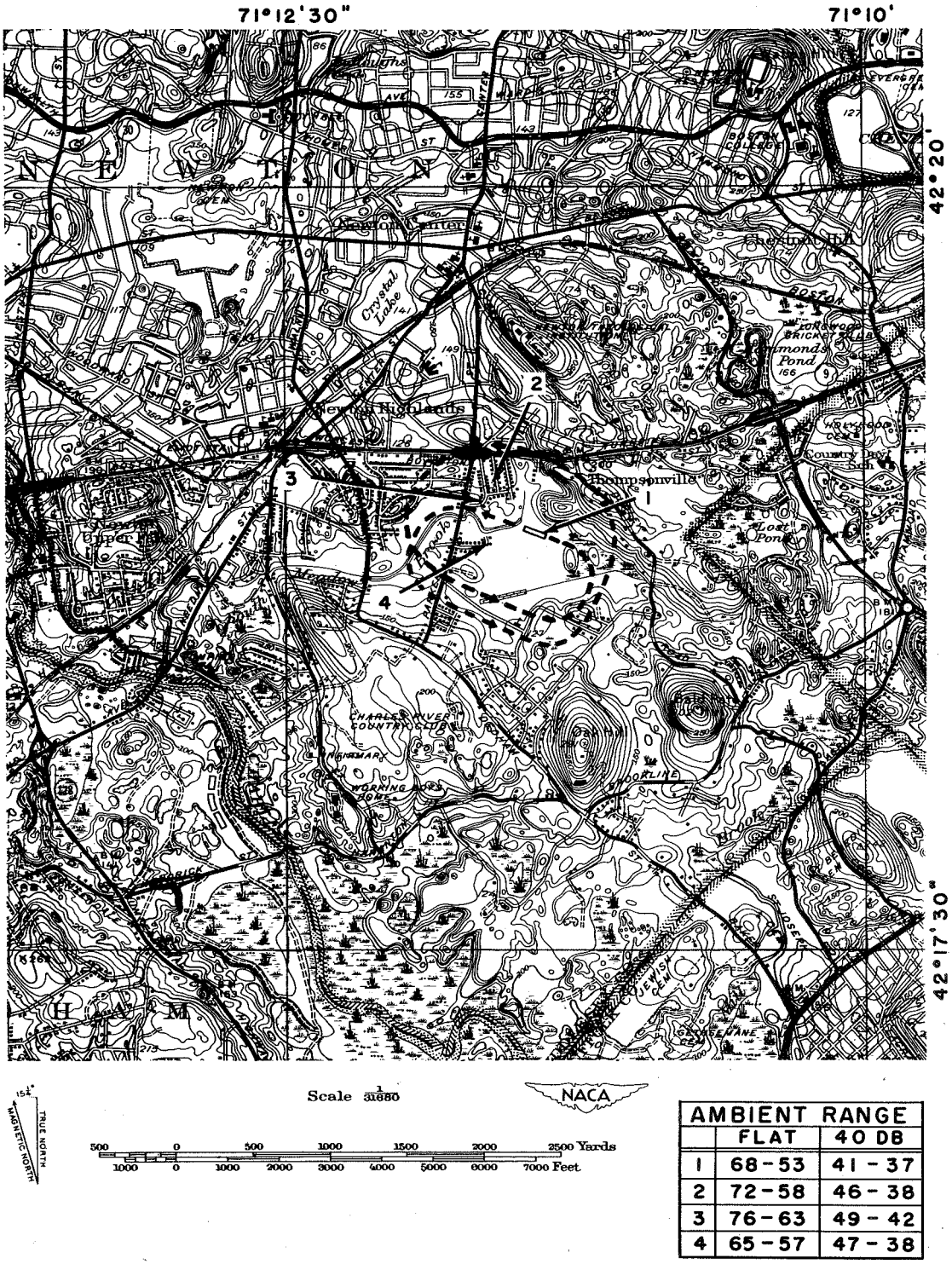
(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 17.- Concluded.



(a) View of site with air traffic pattern superimposed.

Figure 18.- Newton site.



AMBIENT RANGE		
	FLAT	40 DB
1	68 - 53	41 - 37
2	72 - 58	46 - 38
3	76 - 63	49 - 42
4	65 - 57	47 - 38

(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 18.- Concluded.

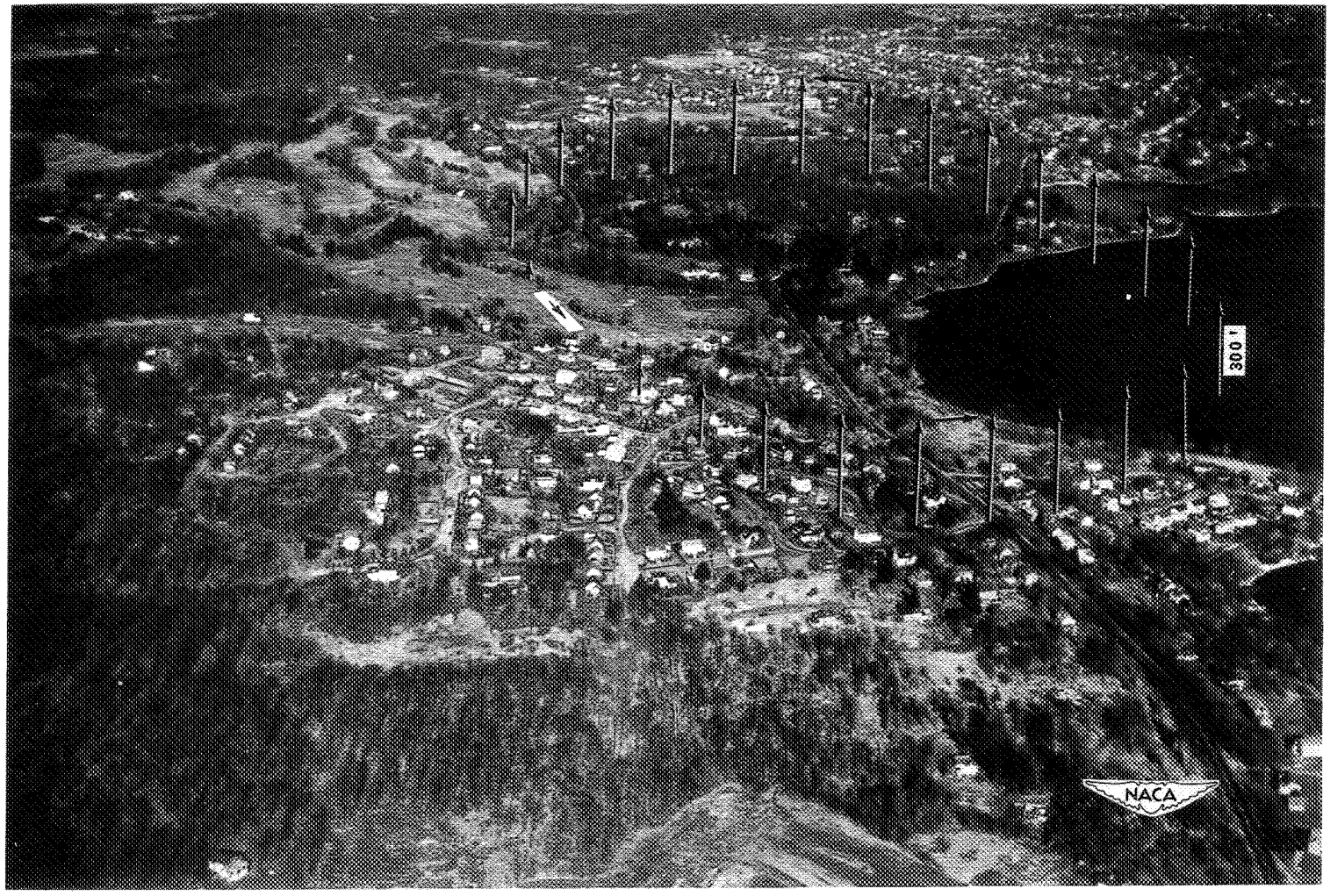
(a) View of site with air traffic pattern superimposed.

Figure 19.- Newton-Brighton site.

AMBIENT RANGE		
	FLAT	40 DB
1	78 - 61	52 - 42
2	96 - 62	71 - 49
3	88 - 60	65 - 47
4	85 - 59	63 - 44

(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 19.- Concluded.



(a) View of site with air traffic pattern superimposed.

Figure 20.- Winchester site.

AMBIENT RANGE		
	FLAT	40 DB
1	62 - 51	46 - 31
2	68 - 54	42 - 36
3	64 - 55	45 - 37

(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 20.- Concluded.

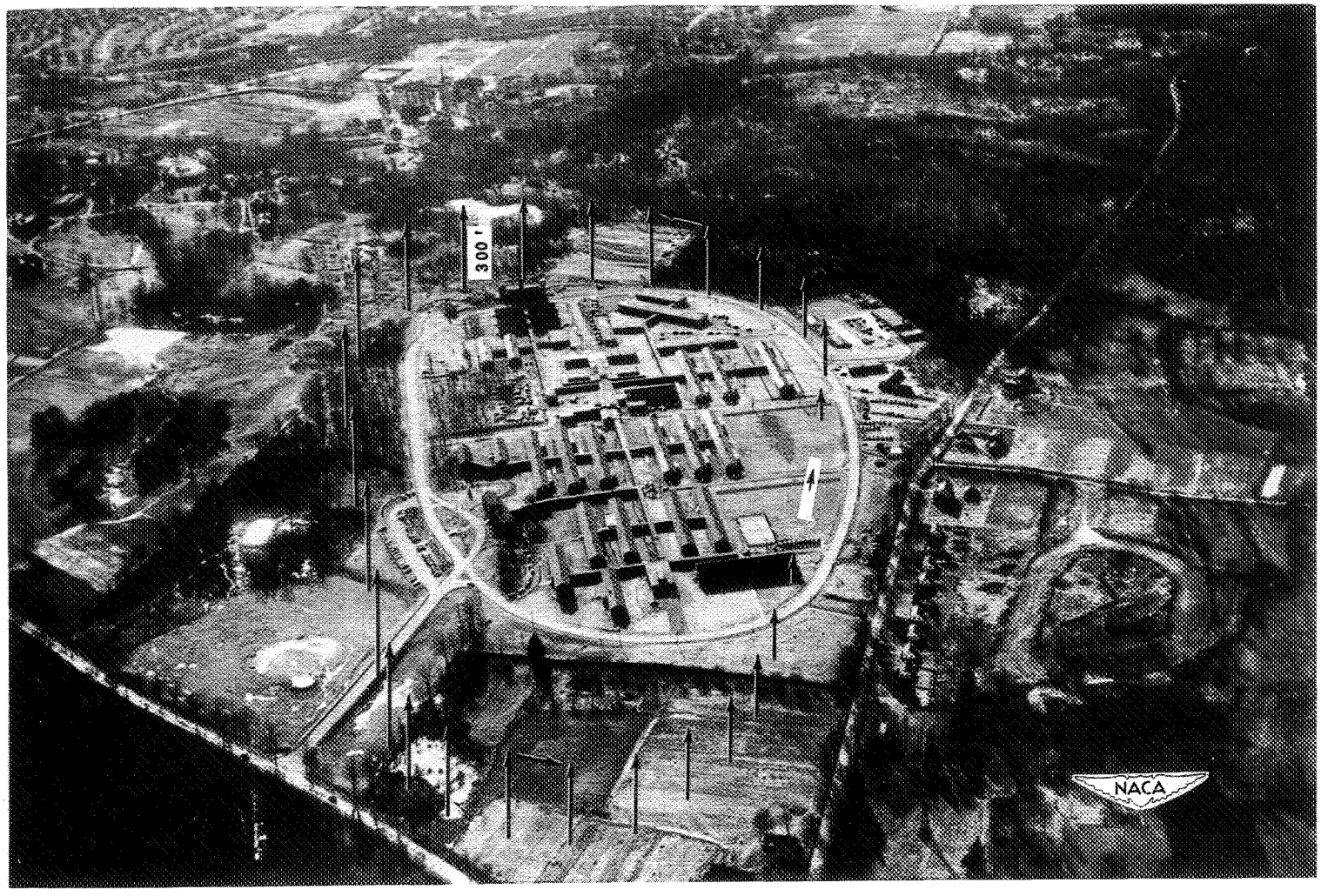
(a) View of site with air traffic pattern superimposed.

Figure 21.- Cambridge site.

AMBIENT RANGE		
	FLAT	40 DB
1	74-62	58-44
2	76-64	61-46
3	71-56	57-40

(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 21.- Concluded.



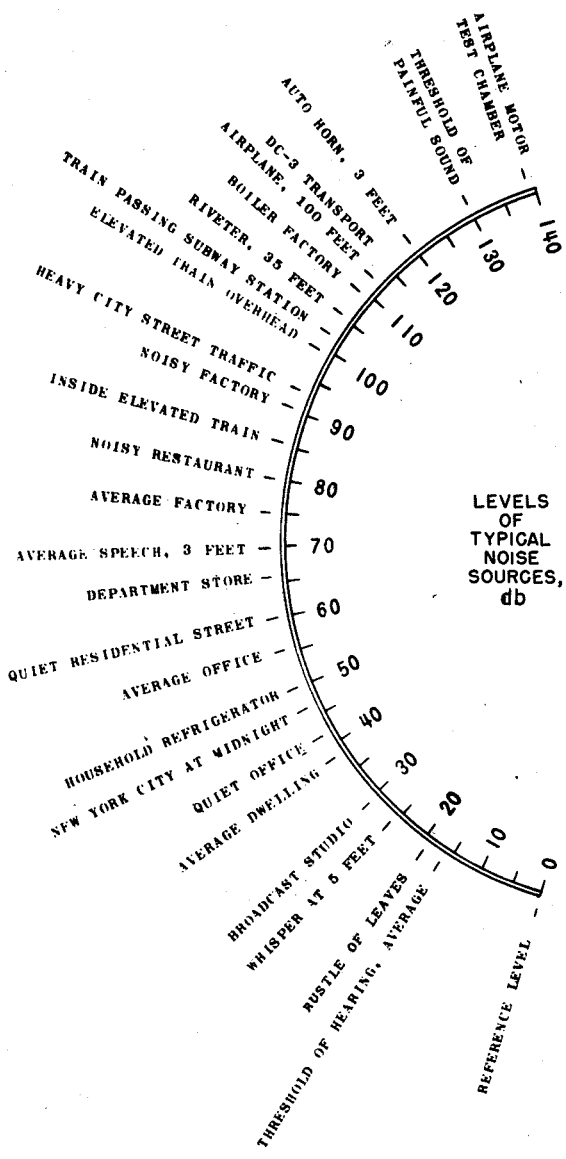
(a) View of site with air traffic pattern superimposed.

Figure 22.- Waltham site.

AMBIENT RANGE		
	FLAT	40 DB
1	70 - 58	48 - 32
2	72 - 59	50 - 33
3	78 - 61	53 - 38

(b) Topographical map of surrounding area with air traffic pattern and ambient levels indicated.

Figure 22.- Concluded.



CODE	AIRPLANE	CONFIGURATION	POWER (hp)
1	ARF CUB	1	45
2	CAA CUB	2M	44
3	CAA CUB	2U	44
4	ARF STINSON	3	96
5	STANDARD CUB	4	44
C	500' CRUISING POWER		

EXAMPLE:

1C = { ARF CUB
500' CRUISING POWER

REFER TO TABLE I

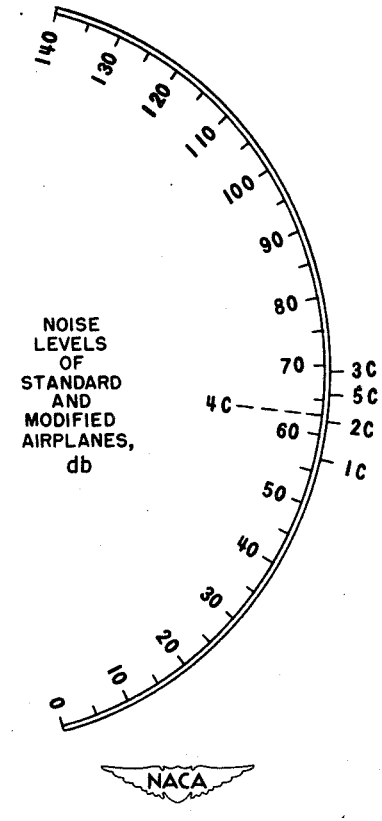


Figure 23.- Noise-level comparisons.

MASSACHUSETTS AERONAUTICS COMMISSION

LOGAN AIRPORT, EAST BOSTON

February 28, 1949

Representative Gerald C. Lucey
State House
Boston 33, Massachusetts

Dear Representative Lucey:

Our inspectors have investigated the flight test activities of the Aeronautical Research Foundation at the Brockton Fairgrounds and find that certain of their procedures can be changed in the interests of safety. We have, therefore, instructed the Foundation to make no more take-offs in a northerly direction where engine failure might possibly create a hazard to persons living just north of the Fairgrounds.

With this limitation, and bearing in mind the special characteristics of the aircraft used and the high degree of proficiency of the pilot, we feel that the flight tests can be continued with every consideration being given to the safety of the surrounding residents.

I assume you know that these tests are being made with an airplane from which most of the noise has been removed for the purpose of determining community reaction to a quiet airplane. Our inspector was surprised to find that most of the complaints were occasioned by the fact that observers thought the aircraft was in trouble and was about to land on the houses or in the street because they heard no noise from the propeller or the power plant. Apparently when the latter was explained a large majority of the persons interviewed had no further objections.

Very truly yours,

Crocker Snow
Director of Aeronautics

CS:pr
cc: Prof. Bollinger
Rep. Arthur Sheehan

EXHIBIT I

Mount Auburn Hospital

330 Mt. Auburn Street
Cambridge 38, Mass.

A. G. ENGELBACH, M.D., F.A.C.H.A.
DIRECTOR

October 4, 1948

Aeronautical Research Foundation
Soldiers' Field Parkway
Boston 63, Massachusetts

Attention: Professor Bollinger, Director

Gentlemen:

At the time the tests were made on the quieted airplane sometime ago,* we had no complaints from the patients that they were annoyed and other witnesses were of the opinion that the demonstration was successful.

Very truly yours,

A. G. Engelbach, M.D.
Director

AGE:cc

* 12/15/47

EXHIBIT 2

NACA-Langley - 5-27-52 - 1000

EXHIBIT 3

Cambridge, Massachusetts
December ~~8~~ 15, 1947

You have been invited today to witness a public demonstration of what is believed to be the first airplane that is both equipped with effective noise reduction devices and is at the same time an efficient vehicle practical for personal flying.

This airplane is a standard Stinson four-passenger 1947 model modified by the Aeronautical Research Foundation, a nonprofit Massachusetts research corporation. The effort to develop and set standards for a quiet "good neighbor" airplane is being federally financed through the National Advisory Committee for Aeronautics, with the active cooperation of the Civil Aeronautics Administration. The personal services of Dr. Lynn L. Bollinger and Mr. Arthur H. Tully, Jr., of Harvard and Professors Otto C. Koppen and C. Fayette Taylor of M.I.T. have made this project possible.

Please remember that this is an experimental airplane in so far as the functioning of the noise reduction devices are concerned. You are witnessing its first flight away from the E. W. Wiggins' shops at Canton airport where it was modified. The pilot Mr. Henry Kent, is considered one of the most experienced and able in the country for this type of flying. He has been carefully instructed to operate the airplane so that any reasonably probable mechanical malfunctioning will not endanger persons or structures on the ground. (The demonstration flight has, of course, been approved by the Director of the Massachusetts Aeronautics Commission and by the local CAA inspector.)

Your opinion of the airplane's "good neighbor" characteristics is earnestly solicited. The primary purpose of this flight is to obtain your judgment as to whether the airplane as now equipped is entirely adequate to fly witnin reasonable distances of dwellings without creating objectionable noise, or whether further silencing devices need be added.

The noise energy output is now approximately 1/~~400~~ 200th that of a conventional airplane. At the Cambridge Boat Club site the sound (when not obscured by passing automobiles) should be approximately twice the intensity as that reaching the hospital exterior walls, and if the estimates are correct, the sound should not be audible inside the hospital or within nearby dwellings (i.e. quieter than existing street traffic). That is the standard by which you are asked to judge the vehicle.

You have purposely been asked to stand outside the "shield" of street traffic noise so that you may detect the nature of the aerodynamic sounds. Please grade the performance of the vehicle by answering the following brief questionnaire:

Cambridge, Massachusetts
December ~~8~~ 15, 1947

to:
The Massachusetts Recess Commission on Aviation
Room 407, State House
Boston 33, Massachusetts

Attention: Mr. Vance L. Alden, Secretary

I have witnessed the first public demonstration of the Aeronautical Research Foundation's experimental "good neighbor" airplane and rate it accordingly:

(Check one)

A. Sufficiently quiet to eliminate all valid noise objections

B. Sufficiently quiet to suit me but possibly objectionable to others

C. Needs slight additional quieting to be entirely acceptable

D. Needs substantial additional quieting to overcome noise objections

If such an airplane were made absolutely inaudible and were to be flown regularly from the location used and in the manner demonstrated would you willingly accept its presence as a "good neighbor"?

Yes
No

(If you vote no, please indicate briefly why.)

Signed_____

Position_____